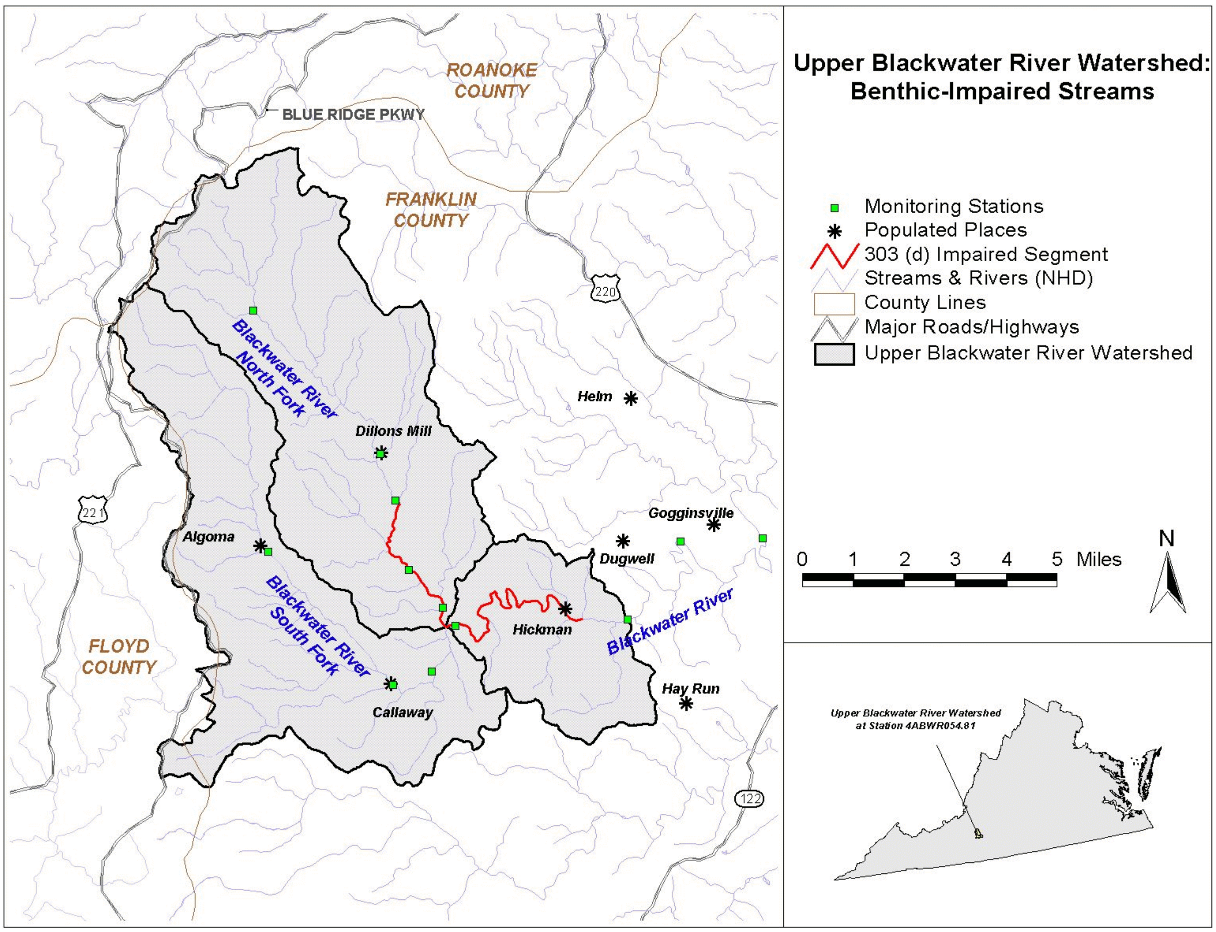
Total Maximum Daily Load (TMDL) Development for the Upper Blackwater River Watershed

Aquatic Life Use (Benthic) Impairment



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Background

The Upper Blackwater River watershed is located in Franklin County, Virginia, in the Roanoke River Basin (USGS Hydrologic Unit Code, 03010101) (Figure 1.1). The watershed lies just north of Rocky Mount, Virginia and approximately 15 miles south of Roanoke, Virginia. The Blackwater River flows southeastward and empties into Smith Mountain Lake. The waterbody identification code (WBID, Virginia Hydrologic Unit) for these streams is VAW-L08R.

Virginia 305(b)/303(d) guidance states that support of the aquatic life beneficial use is determined by the assessment of conventional pollutants (dissolved oxygen, pH, and temperature); toxic pollutants in the water column, fish tissue and sediments; and biological evaluation of benthic community data (VADEQ 1997). Benthic community assessments are, therefore, used to determine compliance with the General Criteria section of Virginia's Water Quality Standards (9 VAC 25-260-20). In general, the stream reach that a biomonitoring station represents is classified as impaired if the EPA's Rapid Bioassessment Protocol (RBP) ranking is either moderately or severely impaired. As a result, the Blackwater River (upper and middle segments) and North Fork Blackwater River were listed as impaired due to violations of the general standard (aquatic life).

Water quality data analyses and field observations indicate that the primary cause of the benthic community impairment in the mainstem and North Fork Blackwater River is increased amounts of sediment. Phosphorus is also identified as a stressor for the North Fork. In order to improve water quality conditions that have resulted in benthic community impairments, Total Maximum Daily Loads (TMDLs) were developed for the impaired streams, taking into account all sources of sediment and phosphorus in the watersheds, plus a margin of safety (MOS).

Upon implementation, the TMDLs will ensure that water quality conditions relating to benthic impairment will meet the allowable loadings estimated by use of a reference watershed (a non-impaired watershed with characteristics similar to those of the impaired watersheds).

Sources of Sediment and Phosphorus

Sediment and phosphorus sources can be divided into point and nonpoint sources. There are three point sources in the Upper Blackwater River watershed (Table 1). Two of the point sources in the watershed were issued VPDES general permits and one was issued a municipal discharge permit. The Clover Meadow Dairy Farm is a combined animal feeding operation (CAFO) and is listed as a no-discharge facility.

Table 1. VPDES point source facilities in the Upper Blackwater River watershed

Stream	Facility Name	VPDES Permit No.	Discharge Type	Design Flow (MGD)	Permitted Concentration (mg/L)	TSS Load (metric tons/year)	Phosphorus Load (metric tons/year)
South Fork Blackwater	Callaway Elementary	VA0088561	Municipal	0.0019	30 TSS	0.0789	
North Fork Blackwater	Clover Meadow Dairy Farm	VPG120013	General - CAFO	N/A	N/A	N/A	N/A
Unnamed Tributary to South Fork Blackwater	VDOT-Franklin County	VAR101262*	General - Stormwater	0.0032	100 TSS	0.447	

*Permitted load for this facility was calculated as the average annual modeled runoff times the area governed by the permit times a maximum TSS concentration of 100 mg/L. Flow was based on the average annual runoff from row crop lands.

Sediment and phosphorus loads are primarily contributed by nonpoint sources in the Upper Blackwater River watershed. The major nonpoint source of sediment and phosphorus in this watershed is agricultural land. Agricultural lands can contribute excessive sediment and phosphorus loads through erosion and build-up/washoff processes. Agricultural lands are particularly susceptible to erosion, which contributes sediment and adsorbed phosphorus loads. Phosphorus is also associated with the land-application of animal waste and failing septic systems.

Modeling

TMDLs were developed using BasinSim 1.0 and the GWLF model. GWLF is a continuous-simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on daily water balance totals that are summed to give monthly values. In order to consider the spatial distribution of sources in the TMDL development, the Upper Blackwater River watershed was divided into 13 subbasins. Using a stream routing and transport module developed by Tetra Tech, the flow and pollutant loadings from each subwatershed are routed through the stream networks. The transport module also has the capability of assessing streambank erosion. The GWLF simulation results, including flow, sediment load, and phosphorus load (North Fork), for each subwatershed are used to drive the stream flow routing, sediment transport, as well as streambank erosion simulation.

Daily streamflow data are needed to calibrate watershed hydrologic parameters in the GWLF model. The USGS streamflow gage (02056900), located near Rocky Mount, was used in a paired watershed approach to calibrate hydrology for both the reference watershed (Big Chestnut Creek) and the impaired watershed (Upper Blackwater River). Flow data were available from this gage for the calibration period: January 1, 1991 - September 30, 1998. The calibration period covered a range of hydrologic conditions, including low- and high-flow conditions as well as seasonal variations. The calibrated GWLF model adequately simulated the hydrology of the impaired watershed.

TMDL development requires the identification of impairment causes and the establishment of numeric endpoints that will allow for the attainment of designated uses and water quality criteria. Numeric endpoints represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. Virginia does not currently have numeric criteria for nutrients (i.e. total phosphorus and total nitrogen), sediment, and other parameters that may be contributing to the impaired condition of the benthic community in these streams. Therefore, a reference watershed approach was used to determine the primary benthic community stressors and to establish numeric endpoints for these stressors. This approach is based on selecting a non-impaired watershed that shares similar land use, ecoregion, and geomorphological characteristics with the impaired watershed. Stream conditions in the reference watershed are assumed to be representative of the conditions needed for the impaired stream to attain its designated uses. Big Chestnut Creek was chosen as the reference watershed and any reductions of sediment and phosphorus from the impaired waterbodies were based on the reference loads of sediment and phosphorus in the Big Chestnut Creek watershed.

Existing Conditions

Impaired and reference watershed models were calibrated for hydrology using different modeling periods and weather input files. To establish baseline (reference watershed) loadings for sediment and phosphorus the GWLF model for Big Chestnut Creek was used. For TMDL calculation both the calibrated reference and impaired watersheds were modeled for a 12 and a half year period from 4/1/1990 to 12/31/2002. This was done to standardize the modeling period. In addition, the total area for the reference watershed was reduced to be equal to its paired target watershed. This was necessary because watershed size influences sediment delivery to the stream and other model variables.

The 12-year means for pollutants of concern were determined for each land use/source category in the reference and the impaired watershed. This modeling period was used, after calibration, to represent a broad range of recent weather and hydrologic conditions.

Margin of Safety

While developing allocation scenarios for the TMDL, an explicit margin of safety (MOS) of ten percent was used. Ten percent of the reference sediment load was calculated and added to the sum of the load allocation (LA) and wasteload allocation (WLA) to produce the TMDL. It is assumed that a MOS of 10% will account for any uncertainty in the data and the computational methodology used for the analysis, as well as provide an additional level of protection for designated uses.

Allocation Scenarios

The recommended scenario for Upper Blackwater River (Tables 2, 3, and 4) are based on maintaining the existing percent load contribution from each source category. Table 2 presents the estimated sediment results for the entire Upper Blackwater River watershed, Table 3 presents the estimated sediment results for the North Fork Blackwater River watershed, and Table 4 presents the estimated phosphorus results for the North Fork Blackwater River watershed. The recommended scenarios balance the reductions from agricultural and urban sources by maintaining existing watershed loading characteristics. Permit requirements are expected to result in attainment of the WLAs as required by the TMDL; therefore, point source loads were not reduced.

Table 2. Recommended sediment allocations for Upper Blackwater River

Source Category	*Existing Loads*		*Allocated Loads (TMDL minus 10 % MOS)*		
	Sediment Load (ton/yr) *	**Sediment % of Total**	**Sediment Load Allocation (ton/yr) ***	**Sediment % of Total**	**Sediment % Reduction**
Row Crop	6,530.1	57.1%	2,347.9	47.1%	64.0%
Pasture/Hay	4,245.6	37.1%	2,010.1	40.3%	52.7%
Pasture/Hay (stream access)	70.0	0.6%	43.5	0.9%	37.8%
DeciduousForest	579.9	5.1%	579.9	11.6%	0.0%
MixedForest	2.8	0.0%	2.8	0.1%	0.0%
Urban	0.0	0.0%	0.0	0.0%	0.0%
Groundwater	0.0	0.0%	0.0	0.0%	0.0%
PointSource	0.526	0.0%	0.526	0.0%	0.0%
Total	**11,428.8**		**4,984.7**		**56.4%**

* Overall loads for sources were calculated by summing the loads from each source in each subbasin.

Table 3. Recommended sediment allocations for North Fork Blackwater River

Source Category	Existing Loads		Allocated Loads (TMDL minus 10 % MOS)		
	Sediment Load (ton/yr) *	Sediment % of Total	Sediment Load Allocation (ton/yr) *	Sediment % of Total	Sediment % Reduction
Row Crop	2,117.5	45.9%	746.3	33.2%	64.8%
Pasture/Hay	2,159.4	46.8%	1,183.3	52.6%	45.2%
Pasture/Hay (stream access)	52.5	1.1%	35.9	1.6%	31.6%
DeciduousForest	280.6	6.1%	280.6	12.5%	0.0%
MixedForest	1.4	0.0%	1.4	0.1%	0.0%
Urban	0.0	0.0%	0.0	0.0%	0.0%
Groundwater	0.0	0.0%	0.0	0.0%	0.0%
PointSource	0.0	0.0%	0.0	0.0%	0.0%
Total	**4,611.5**		**2,247.5**		**51.3%**

* Overall loads for sources were calculated by summing the loads from each source in each subbasin.

Table 4. Recommended total phosphorus allocations for North Fork Blackwater River

Source Category	Existing Loads		Allocated Loads (TMDL minus 10 % MOS)		
	TP Load (ton/yr) *	TP % of Total	TP Load Allocation (ton/yr) *	TP % of Total	TP % Reduction
Row Crop	1.824	36%	0.702	22%	61%
Pasture/Hay	2.116	42%	1.368	44%	35%
Pasture/Hay (stream access)	0.112	2%	0.080	3%	28%
DeciduousForest	0.199	4%	0.199	6%	0%
MixedForest	0.001	0%	0.001	0%	0%
Urban	0.079	2%	0.070	2%	12%
Groundwater	0.638	13%	0.638	20%	0%
PointSource	0.000	0%	0.000	0%	0%
Septic System	0.097	2%	0.073	2%	24%
Total	**5.066**		**3.132**		**38.2%**

The TMDLs established for these streams consist of a point source wasteload allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS). The sediment TMDLs were based on the total load calculated for the Twittys Creek watershed (area adjusted to the appropriate watershed size).

The TMDL equation is as follows:

TMDL = WLA + LA + MOS

The WLA portion of this equation is the total loading assigned to point sources. The LA portion represents the loading assigned to nonpoint sources. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis.

TMDLs were calculated by adding reference watershed loads for sediment together with point source loads to give the TMDL value (Tables 5, 6, and 7).

Table 5. Sediment TMDL for Upper Blackwater River

Stream	Pollutant	TMDL (tons/yr)	LA (tons/yr)	WLA (tons/yr)	MOS (10%) (tons/yr)	Overall % Reduction
Upper Blackwater River	Sediment	5538.6	4984.2	0.526 *(Callaway Elementary School = 0.0789; VDOT = 0.447)*	553.9	56.4%

Table 6. Sediment TMDL for North Fork Blackwater River

Stream	Pollutant	TMDL (tons/yr)	LA (tons/yr)	WLA (tons/yr)	MOS (10%) (tons/yr)	Overall % Reduction
North Fork Blackwater River	Sediment	2497.3	2247.5	0.00	249.7	51.3%

Table 7. Total phosphorus TMDL for North Fork Blackwater River

Stream	Pollutant	TMDL (tons/yr)	LA (tons/yr)	WLA (tons/yr)	MOS (10%) (tons/yr)	Overall % Reduction
North Fork Blackwater River	Total Phosphorus	3.480	3.132	0.00	0.348	38.2%

SECTION 1

INTRODUCTION

1.1 Background

1.1.1 TMDL Definition and Regulatory Information

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are exceeding water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of their water resources (USEPA 1991).

1.1.2 Impairment Listing

The Blackwater River and North Fork Blackwater River were listed as impaired on Virginia's Section 303(d) Total Maximum Daily Load Priority List and Report due to violations of the General Standard (VADEQ 1996, 1998, and 2002). This designation was based on benthic macroinvertebrate community assessments conducted since 1996 which indicate partial or non-support of the Aquatic Life Use. In 1996, the Blackwater River mainstem (upper and middle segments) was listed as impaired from the confluence of the North and South Forks downstream to an unnamed tributatry located approximately 1 mile downstream of a private bridge off Rt. 921. The entire length of the North Fork Blackwater River was listed as impaired in 1996. The upstream limit of the North Fork Blackwater impaired segment was re-designated at the Rt. 739 bridge crossing in 1998 based on biomonitoring data collected since 1996. Recent data indicates improved conditions in the Middle Blackwater River segment and the lower portion of the Upper Blackwater River segment. Based on these data, the Upper Blackwater River impaired segment currently includes that portion of the river from the North Fork/South Fork confluence to approximately 0.10 miles below Rt. 737 (Hickman Rd.) (5.62 miles in length). The North Fork Blackwater River impaired segment remains unchanged from the 1998 listing (3.26 miles in length). The current reference site used in bioassessment is located on Big Chestnut Creek, just below the Rt. 715 bridge crossing (transitional Blue Ridge to Piedmont). The Aquatic Life Use is also listed as threatened for 20.86 miles on the Blackwater river due to periodic exceedances of the phosphorus threshold value of 0.2 mg/L. In addition, the North Fork, South Fork, Upper, and Middle Blackwater River segments were listed as impaired due to high bacteria concentrations. TMDLs for fecal coliform bacteria were developed by the Commonwealth of Virginia in October 2000 (VADEQ and VADCR 2000). This report specifically addresses the benthic community impairments in the Upper Blackwater River watershed.

1.1.3 Watershed Location

The Upper Blackwater River watershed is located in Franklin County, Virginia, in the Roanoke River Basin (USGS Hydrologic Unit Code, 03010101) (Figure 1.1). The watershed is located just north of Rocky Mount, Virginia and approximately 15 miles south of Roanoke, Virginia. The Blackwater River flows southeastward and empties into Smith Mountain Lake. The waterbody identification code (WBID, Virginia Hydrologic Unit) is VAW-L08R.

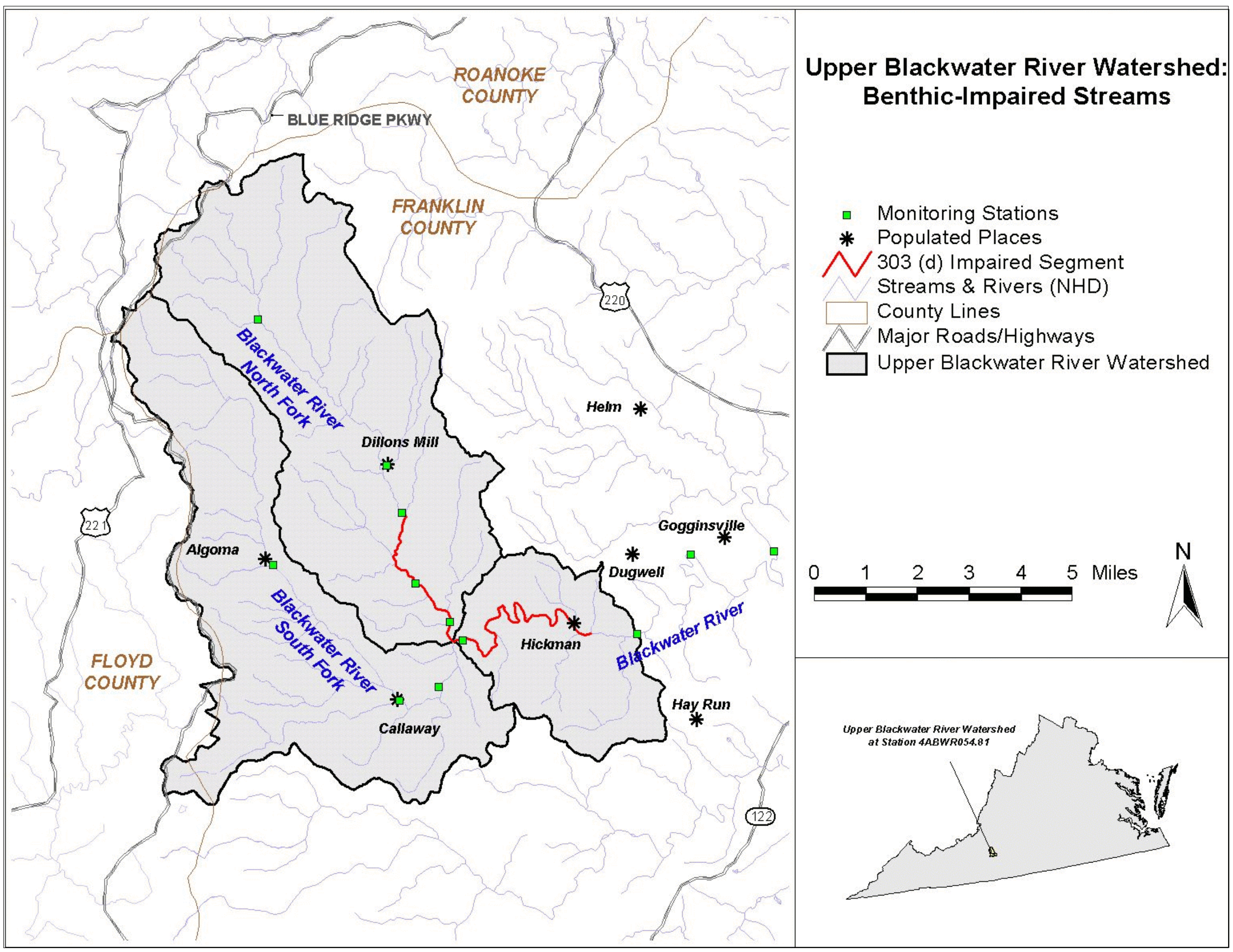


Figure 1-1 Location of impaired watershed

1.2 Designated Uses and Applicable Water Quality Standards

According to Virginia Water Quality Standards (9 VAC 25-260-5), the term "Water quality standards" *means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§ 62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC § 1251 et seq.).*

1.2.1 Designation of Uses (9 VAC 25-260-10)

A. All state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish).

The North Fork and Upper Blackwater River impaired segments do not support the aquatic life designated use due to violations of the general (benthic) criteria (see Section 1.2.2).

1.2.2 Water Quality Standards

General Criteria (9 VAC 25-260-20)

A. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life.

Specific substances to be controlled include, but are not limited to: floating debris, oil scum, and other floating materials; toxic substances (including those which bioaccumulate); substances that produce color, tastes, turbidity, odors, or settle to form sludge deposits; and substances which nourish undesirable or nuisance aquatic plant life. Effluents which tend to raise the temperature of the receiving water will also be controlled.

1.3 Biomonitoring and Assessment

Direct investigations of biological communities using rapid bioassessment protocols, or other biosurvey techniques, are best used for detecting aquatic life impairments and assessing their relative severity (Plafkin et al. 1989). Biological communities reflect overall ecological integrity; therefore, biosurvey results directly assess the status of a waterbody relative to the primary goal of the Clean Water Act. Biological communities integrate the effects of different pollutant stressors and thus provide a holistic measure of their aggregate impact. Communities also integrate the stresses over time and provide an ecological measure of fluctuating environmental conditions.

Many state water quality agencies use benthic macroinvertebrate community data to assess the biological condition of a waterbody. Virginia uses EPA's Rapid Bioassessment Protocol (RBP II) to determine the status of a stream's benthic macroinvertebrate community. This procedure relies on comparisons of the benthic macroinvertebrate community between a monitoring station and its designated reference site. Measurements of the benthic community, called metrics, are used to identify differences between monitored and reference stations. Metrics used in the RBP II protocol include taxa richness, percent contribution of dominant family, and other measurements that provide information on the abundance of pollution tolerant versus pollution intolerant organisms. Biomonitoring stations are typically sampled in the spring and fall of each year. The biological condition scoring criteria and the bioassessment matrix are discussed in the technical document, *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish* (Plafkin et al. 1989). The RBPII bioassessment scoring matrix is presented in Table 1.1.

Table 1.1 Bioassessment scoring matrix (Plafkin et al. 1989)

% Compare to Reference Score (a)	Biological Condition Category	Attributes
>83%	Non-Impaired	Optimum community structure (composition and dominance).
54 - 79%	Slightly Impaired	Lower species richness due to loss of some intolerant forms.
21 - 50%	Moderately Impaired	Fewer species due to loss of most intolerant forms.
<17%	Severely Impaired	Few species present. Dominant by one or two taxa. Only tolerant organisms present.
(a) Percentage values obtained that are intermediate to the above ranges require subjective judgement as to the correct placement.		

Virginia 305(b)/303(d) guidance states that support of the aquatic life beneficial use is determined by the assessment of conventional pollutants (dissolved oxygen, pH, and temperature); toxic pollutants in the water column, fish tissue and sediments; and biological evaluation of benthic community data (VADEQ 1997). Benthic community assessments are, therefore, used to determine compliance with the General Criteria section of Virginia's Water Quality Standards (9 VAC 25-260-20). In general, the stream reach that a biomonitoring station represents is classified as impaired if the RBP ranking is either moderately or severely impaired. As a result, these streams were listed as impaired due to violations of the general standard (aquatic life).

SECTION 2

BENTHIC TMDL ENDPOINT DETERMINATION

2.1 Reference Watershed Approach

Biological communities respond to any number of environmental stressors, including physical impacts and changes in water and sediment chemistry. According to Virginia's 2002 303(d) list, the probable causes of benthic impairment include nonpoint source runoff from agricultural activity and streambank modification.

TMDL development requires the identification of impairment causes and the establishment of numeric endpoints that will allow for the attainment of designated uses and water quality criteria. Numeric endpoints represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. Virginia does not currently have numeric criteria for nutrients (i.e. total phosphorus and total nitrogen), sediment, and other parameters that may be contributing to the impaired condition of the benthic community in these streams. A reference watershed approach was, therefore, used to determine the primary benthic community stressors and to establish numeric endpoints for these stressors. This approach is based on selecting non-impaired watersheds that share similar land use, ecoregion, and geomorphological characteristics with the impaired watershed. Stream conditions in the reference watershed are assumed to be representative of the conditions needed for the impaired stream to attain its designated uses. The Virginia Stream Condition Index (VaSCI) was used to define differences in the benthic communities in impaired and reference streams (USEPA 2003a). Loading rates for pollutants of concern are determined for impaired and reference watersheds through modeling studies. Both point and nonpoint sources are considered in the analysis of pollutant sources and in watershed modeling. Numeric endpoints are based on reference watershed loadings for pollutants of concern and load reductions necessary to meet these endpoints are determined. TMDL load allocation scenarios are then developed based on an analysis of the degree to which contributing sources can be reasonably reduced.

2.2 Watershed Characterization

2.2.1 General Information

The Blackwater River watershed is located in Franklin County, Virginia, in the Roanoke River Basin (USGS Hydrologic Unit Code, 03010101) (Figure 1.1). The watershed is located approximately 15 miles south of Roanoke, Virginia. The waterbody identification code (WBID, Virginia Hydrologic Unit) is VAW-L08R. The North Fork Blackwater River was listed as impaired from the Rt. 739 bridge downstream to the mouth (3.26 miles). The Upper Blackwater River was listed as impaired from the confluence of the North and South Forks to approximately 0.10 miles below Rt. 737

(Hickman Rd.) (5.62 miles in length). The total area of the Upper Blackwater River watershed is approximately 71 square miles or 45,262 acres.

2.2.2 Geology

The Blackwater River is located in the transitional Blue Ridge to Piedmont physiographic province. The Blue Ridge is composed of mountainous ridges underlain by resistant and deformed metavolcanic, igneous, sedimentary, and metasedimentary rock. Inceptisols, Ultisols and Alfisols have developed on the Cambrian, Paleozoic, and Precambrian rock (Woods et al. 1999).

The Piedmont is underlain primarily by deep weathered, deformed metamorphic rocks that have been intruded by igneous material. Sedimentary rocks are also found, but are much less dominant than in the Middle Atlantic Coastal Plain or the Southeastern Plains. Utisols occur widely and have developed from residuum. They are commonly clay-rich, acid and relatively low in base saturation (Woods et al. 1999).

2.2.3 Soils

Soils data were obtained from State Soil Geographic (STATSGO) database which includes general soils data and map unit delineations for the United States. GIS coverages provide accurate locations for the soil map units (MUIDs) at a scale of 1:250,000 (USDA 1995). A map unit is composed of several soil series having similar properties. STATSGO map units that cover a portion of the Upper Blackwater River watershed are shown in Figure 2.1. The following soil descriptions are based on NRCS Official Soil Descriptions (1998-2002).

STATSGO Soil Type VA007 is composed of the Hayesville series, the Parker Series, the Peaks series, and the Eubanks series. The Hayesville series accounts for 85% of the map unit. The Hayesville series consists of very deep, well drained soils on gently sloping to very steep ridges and side slopes of the Southern Appalachian Mountains. They are most commonly formed in residuum weathered from igneous and high-grade metamorphic rocks such as granite, granodiorite, mica gneiss and schist; but in some places formed from thickly-bedded metagraywacke and metasandstone. On steeper slopes the upper part of some pedons may have some colluvial influence. Slopes range from 2% to 60%. Hydrologic soil group - B.

STATSGO Soil Type VA019 is composed of the Cecil series, the Madison series, the Enon series, the Wilkes series, and the Chewacla series. The Cecil series accounts for 78% of the map unit. The Cecil series consists of very deep, well drained moderately permeable soils formed in residuum weathered from felsic, igneous and high-grade metamorphic rocks of the Piedmont uplands. The series is located on ridges and side slopes of the Piedmont uplands. Permeability is moderate and slopes range from 0% to 25%. Hydrologic soil group - B.

STATSGO Soil Type VA020 is composed of Rubble Land, the Porter series, the Hayesville series, the Peaks series, and the Chester series. Rubble Land accounts for 55% of the map unit. Rubble Land is not a soil series, but consists of areas of cobbles, stones, and boulders. Rubble land is commonly at the base of mountains but some areas are deposits of cobbles, stones, and boulders left on mountainsides by glaciation or by periglacial processes. Permeability is high. Hydrologic soil group - A.

STATSGO Soil Type VA033 is composed of the Turbeville series, the State series, the Dogue series, the Chewacla series, the Wehadkee series, the August series, the Edgehill series, the Hiwassee series, and the Congaree series. The Turbeville series accounts for 61% of the map unit. Soils of the Turbeville series are very deep and well drained. They formed in old alluvium. They are nearly level to steep soils on high terraces in the Piedmont and upper Coastal Plains. Slope ranges from 0% to 35%. Hydrologic soil group - C.

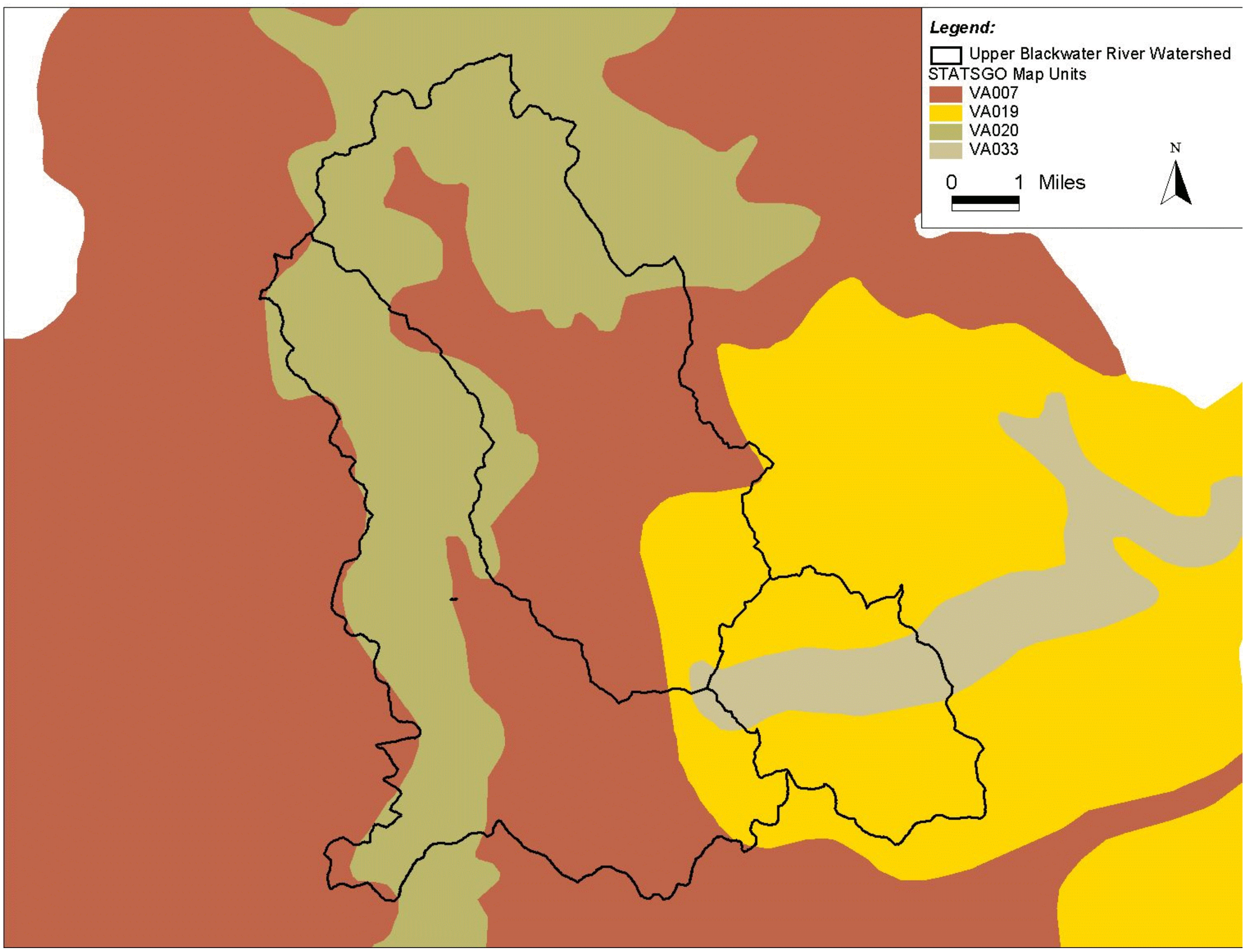


Figure 2.1 STATSGO coverage for the Upper Blackwater River watershed

2.2.4 Climate

The area's climate is typical of other transitional Blue Ridge to Piedmont areas in Virginia. Weather data for the watershed can be characterized using the Rocky Mount meteorological station (NCDC Station VA7338) (period of record: 1948-2003). The growing season lasts from April 25 through October 16 in a typical year (SERCC 2003). Average annual precipitation is 44.17 inches with July having the highest average precipitation (4.68 inches). Average annual snowfall is 16.5 inches, most of which occurs in January and February. The average annual maximum and minimum daily temperature is 67.3°F and 43.7°F, respectively. The highest monthly temperatures are recorded in July (86.6°F - avg. max.) and the lowest temperatures are recorded in January (25.5°F - avg. min.).

2.2.5 Land Use

A detailed land use coverage for the Blackwater River watershed was developed by MapTech, Inc. and Ferrum College for the Virginia Department of Conservation and Recreation (MapTech/Ferrum College 1999). This information was originally derived for the Blackwater River Riparian NPS Pollution Control Project and updated during fecal coliform bacteria TMDL development (VADEQ and VADCR 2000). Land uses in the watershed include various urban, agricultural, and forest categories (Table 2.1 and Figure 2.2). Land use is dominated by forest and agricultural land. Individual land use types were consolidated into broader categories that had similar erosion/pollutant transport attributes for modeling.

Table 2.1. Land use in the Upper Blackwater River watershed

Land Use Type	North Fork Blackwater Watershed (acres)		Upper Blackwater River Watershed (acres)	
	Acres	%of Total	Acres	%of Total
Streams/Lakes/Ponds	525.2	2.56%	1,138	2.51%
Urban	2.4	0.01%	9.5	0.02%
Moderate Septic/Urban Link	215.3	1.05%	444.8	0.98%
Severe Septic/Urban Link	205.8	1.00%	435.3	0.96%
Mostly Wooded	14,361.5	70.05%	31,133.8	68.8%
Livestock Stream Access	92.3	0.45%	153.8	0.34%
Crop Land	1,067.1	5.20%	3,627	8.01%
Hay/Grass/Crop	894.3	4.36%	2,526.9	5.58%
Pasture Land	3,011.9	14.69%	5,451.2	12.04%
Watershed Boundary	56.8	0.28%	123	0.27%
HU Boundary (Hydrologic Unit Boundary)	68.6	0.33%	229.5	0.51%
Total	20,501.2	100%	45,272.9	100%

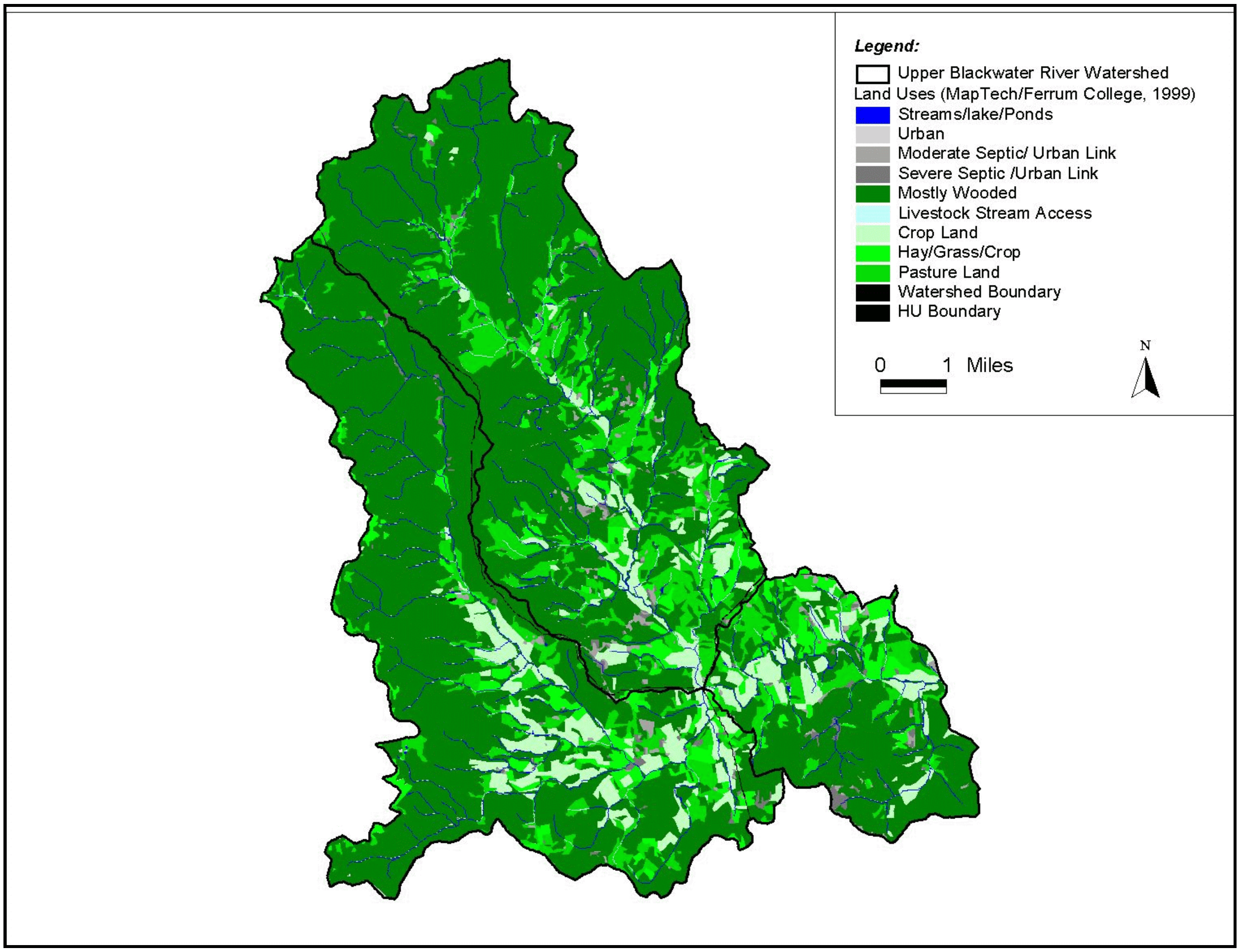


Figure 2.2 Detailed land use coverage for the Upper Blackwater River watershed

2.2.6 Ecoregion

The Upper Blackwater River watershed is located in the Blue Ridge Mountains and Piedmont ecoregions - Level III classifications 66 and 45, respectively (Woods et al. 1999) (Figure 2.3). The Blue Ridge Mountains ecoregion extends from southern Pennsylvania to northern Georgia and is a narrow strip of mountainous ridges that are forested and well dissected. The rugged terrain is composed primarily of metamorphic rocks, with minor areas of igneous and sedimentary geology. It is one of the most diverse ecoregions, and includes Appalachian oak forests, northern hardwoods, and, at the highest elevations, southeastern spruce-fir forests. Streams are cool and clear and have many riffle sections.

The Piedmont ecoregion extends from Wayne County, Pennsylvania, southwest through Virginia. It is characterized by irregular plains, low rounded hills and ridges, shallow valley and scattered monadnocks. It is mostly forested and is a transition zone between the mountainous ecoregions to the west and the flatter coastal ecoregions to the east. The Piedmont is underlain with deeply weathered, deformed metamorphic rocks with intrusions by igneous material. The humid, warm temperate climate originally supported Oak-Hickory-Pine forests with much of the forest lost to agriculture, causing significant soil loss. Stream gradients are typically low to moderate with the moderate gradient streams concentrated in the hillier areas. Falls, islands and rapids and associated fish assemblages are found along the eastern border of the Piedmont in the Fall Zone.

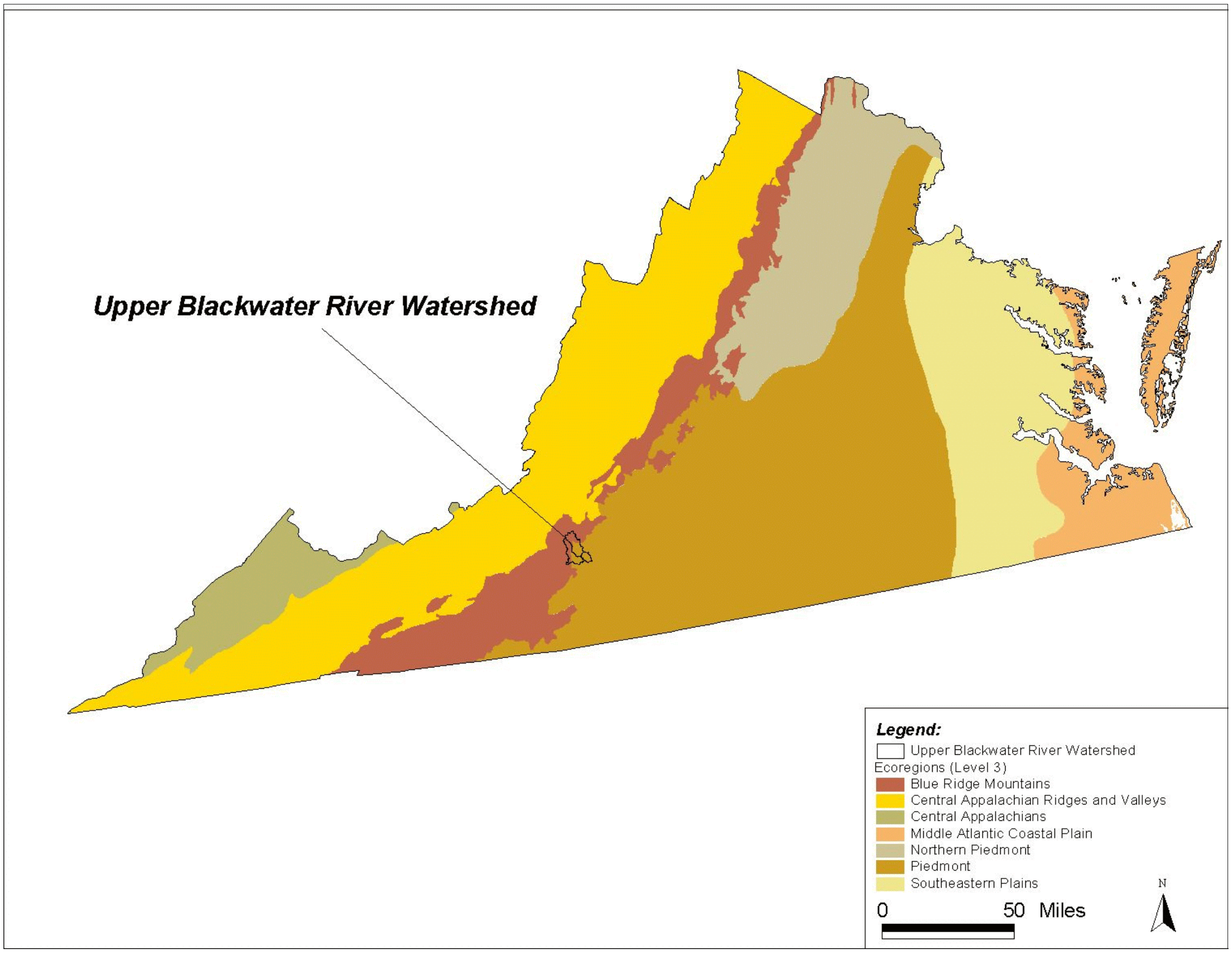


Figure 2.3 Virginia level 3 ecoregions

At a finer scale, the Upper Blackwater River watershed is located in the Interior Plateau, Southern Igneous Ridges, and Northern Inner Piedmont Valleys subecoregions - Level IV classifications 66c, 66d, and 45e, respectively (Woods et al. 1999) (Figure 2.4).

Only the far west edges of the Blackwater River watershed occupy the Interior Plateau subecoregion. This area is characterized by high, hilly plateau dotted with isolated monadnocks. The highest elevations of the region range from 2,600 to 4,500 feet. The Interior Plateau is underlain by Precambrian metamorphic rock, including quartzite, graywacke, and a conglomerate of the Lynchburg formation. Gneiss and schist are also found as outcrops. The region was once dominated by Appalachian Oak Forest and Oak-Hickory-Pine Forest (Kuchler, 1964). Forested areas are broken by pasture and livestock farms.

The western areas of the North and South Fork Blackwater River watersheds are characterized as Southern Igneous Ridges and Mountains. This region is composed of high ridges and mountain masses separated by gaps and coves. The highest ridges of the area can have elevations that range between 2,600 to 5,728 feet. Precambrian and Paleozoic rock underlies the area and outcrops of the Mt. Rogers Volcanic Group, the Virginia Blue Ridge Complex, and Lynchburg Formations are common. The natural vegetation of the area is thick Oak Forest, and at higher elevations, Northern Hardwoods (Kuchler 1964). Today the region is still largely forested.

The eastern areas of the North and South Fork Blackwater River watersheds and the Blackwater mainstem occupy the Northern inner Piedmont subecoregion. The landscape of the area is a mix of hills, irregular plains, and isolated ridges, and mountains. Elevations are typically between 200 to 1,000 feet, but can reach height of 2,000 on isolated monadnocks. The geology of the area is characterized by highly deformed and deeply weathered Cambrian and Proterozoic feldspathic gneiss, schist, and melange. This bedrock is intruded by plutons and covered in clay-rich weathering products. The streams of the area have silt, sand, gravel, and rubble bottoms materials and bedrock is only occasionally exposed. The potential natural vegetation of the area is mapped as Oak-Hickory-Pine forest by Kuchler (1964). Today, shortleaf pine forests are common. Dominant landuses include forestry and agricultural activity.

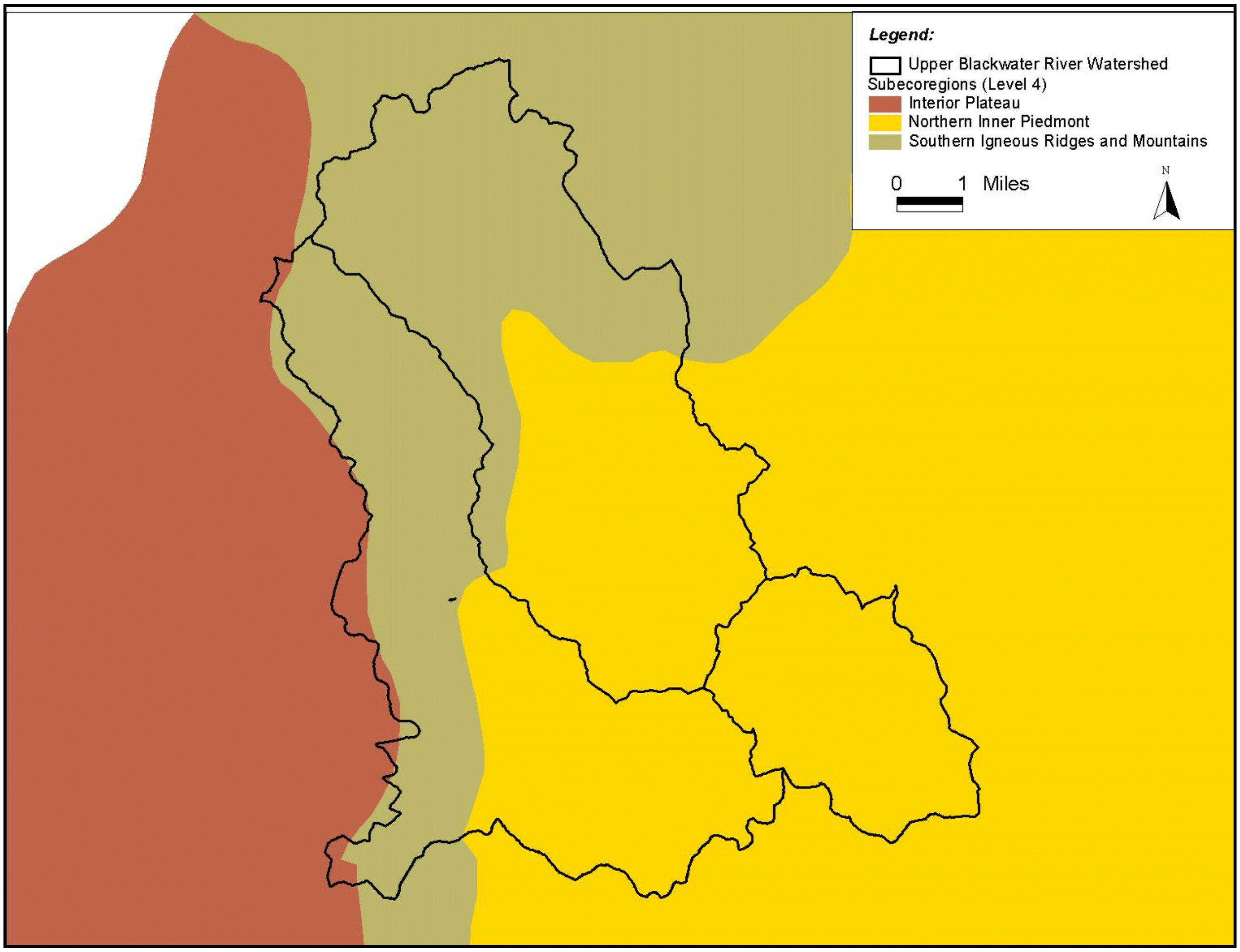


Figure 2.4 Virginia level 4 ecoregions

2.3 Reference Watershed Selection

The reference watershed selection process is based on a comparison of key watershed, stream and biological characteristics. The goal of the process is to select one or several similar, unimpaired reference watersheds that can be used to identify benthic community stressors and develop TMDL endpoints. Reference watershed selection was based on the results of VADEQ biomonitoring studies and comparisons of key watershed characteristics. Data used in the reference watershed selection process are shown in Table 2.2.

Table 2.2 Reference watershed selection data

Biomonitoring Data	Ecoregion Coverages
Topography	Land use Distribution
Soils	Watershed Size
Water Quality Data	Point Source Inventory

Tetra Tech, VADEQ, and USEPA recently developed the Virginia Stream Condition Index (VaSCI), which provides a more detailed and reliable assessment of the benthic macroinvertebrate community in Virginia's non-coastal, wadeable streams (USEPA 2003a). This new multi-metric index was used to compare relative differences in the benthic community between impaired and reference streams. This index allows for the evaluation of biological condition as a factor in the reference watershed selection process and can be used to measure improvements in the benthic macroinvertebrate community in the future. VADEQ biomonitoring data were used to calculate the Tt Draft Index scores shown in Table 2.4. The Big Chestnut Creek reference scores are shown for comparison.

Table 2.3 Bioassessment index comparison

Station ID	Stream	No. of Samples	Tt Draft Index
			Mean (Median)
Current TMDLs			
BNR003.21	Blackwater R., North Fork	3	53 (55)
BNR001.53	Blackwater R., North Fork	3	53 (56)
BNR000.40	Blackwater R., North Fork	16	38 (40)
GCR000.01	Green Creek	13	67 (66)
BSF002.34	Blackwater R., South Fork	2	61 (61)
BWR061.20	Blackwater R.	13	52 (55)
BWR049.73	Blackwater R.	1	65
BWR045.80	Blackwater R.	15	60 (61) mean since 1998=62
Reference Streams			
CNT001.32	Big Chestnut Creek	3	73 (77)

2.4 Selected Reference Watershed

The Big Chestnut Creek watershed, delineated at the VADEQ biomonitoring station, was selected as the reference for these TMDLs (Figure 2.5). This determination was based on the degree of similarity between this stream and its associated watershed to the impaired streams and the results of the VaSCI scores.

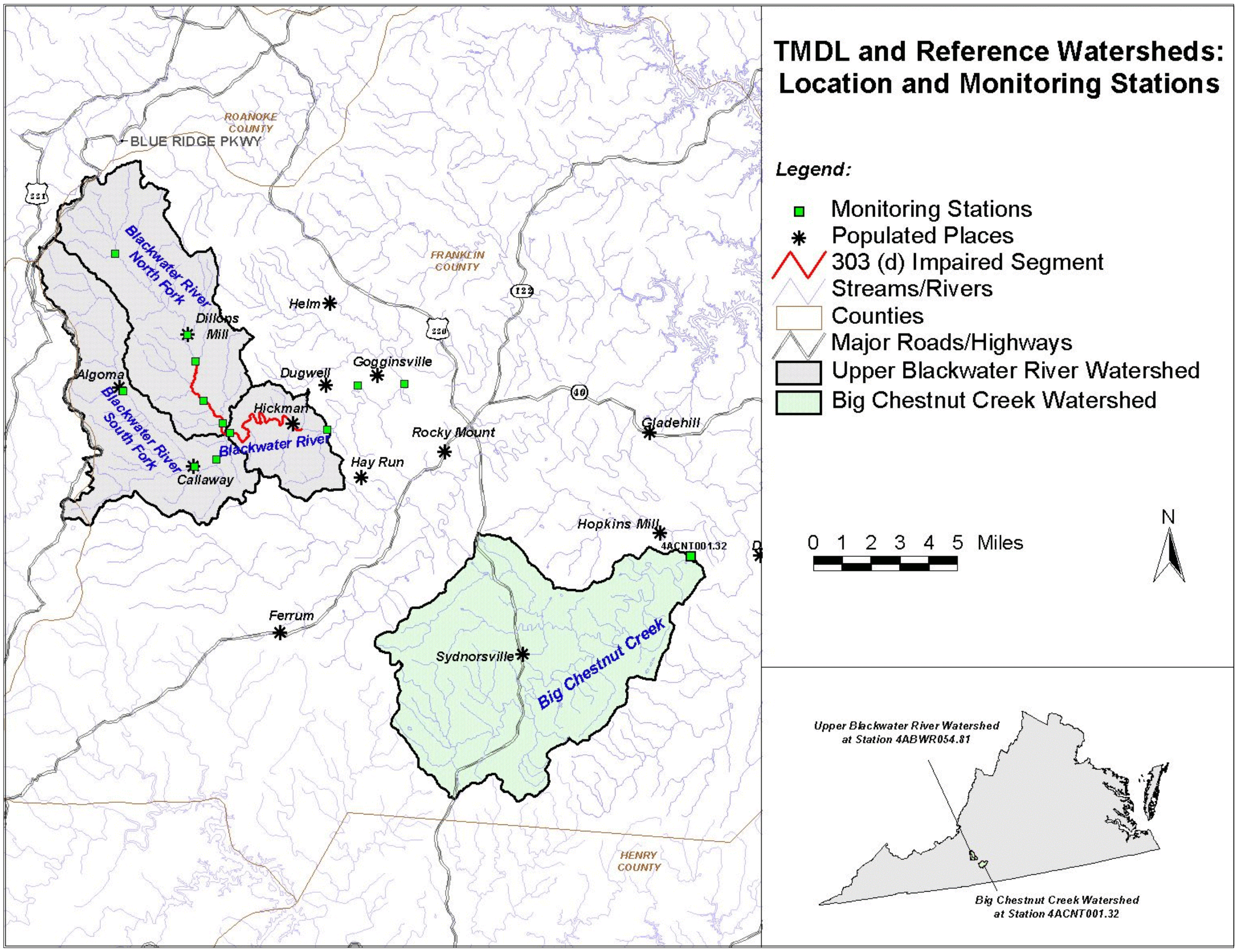


Figure 2.5 TMDL and reference watersheds location and monitoring stations

SECTION 3

STRESSOR IDENTIFICATION

3.1 Stressor Identification Process

Biological assessments are useful in detecting impairment, but they do not necessarily identify the cause(s) of impairment. EPA developed the *Stressor Identification: Technical Guidance Document* to assist water resource managers in identifying stressors or combinations of stressors that cause biological impairment (Cormier et al. 2000). Elements of the stressor identification process were used to evaluate and identify the primary stressors of the benthic communities in the North Fork Blackwater River and Upper Blackwater River segments. Watershed and water quality data from these streams, reference watershed data, and field observations were used to help identify candidate causes.

3.2 Candidate Causes

Based on information provided by VADEQ and watershed data collected at the beginning of the TMDL study, it was hypothesized that sedimentation, excessive nutrient input, and low dissolved oxygen levels were primarily responsible for the listed benthic impairments. A field visit was conducted by Tetra Tech, VADEQ, and VADCR personnel on October 7, 2002 to gather additional information on stream and watershed characteristics for stressor identification and modeling studies. Potential stressors and their relationships to benthic community condition are discussed below.

3.2.1 Low Dissolved Oxygen

Organic enrichment can cause low dissolved oxygen (DO) levels which stress benthic organisms. In general, high nitrogen and phosphorus levels can lead to increased production of algae and macrophytes, which can result in the depletion of oxygen in the water column through metabolic respiration. In addition, at higher water temperatures the concentration of dissolved oxygen is lower because the solubility of oxygen (and other gases) decreases with increasing temperature. Higher water temperatures can be caused by the loss of shading, higher evaporation rates, reduced stream flow, and other factors.

Aquatic organisms, including benthic macroinvertebrates, are dependent upon an adequate concentration of dissolved oxygen. Less tolerant organisms generally cannot survive or are outcompeted by more tolerant organisms under low dissolved oxygen conditions. This process reduces diversity and alters community composition from a natural state. Aquatic insects and other benthic organisms serve as food items for fishes, therefore, alterations in the benthic community can impact fish feeding ecology (Hayward and Margraf 1987; Leach et al. 1977).

3.2.2 Sedimentation

Excessive sedimentation from anthropogenic sources is a common problem that can impact the stream biota in a number of ways. Deposited sediments reduce habitat complexity by filling pools, critical riffle areas, and the interstitial spaces used by aquatic invertebrates. Substrate size is a particularly important factor that influences the abundance and distribution of aquatic insects. Sediment particles at high concentrations can directly affect aquatic invertebrates by clogging gill surfaces and lowering respiration capacity. Suspended sediment also increases turbidity in the water column which can affect the feeding efficiency of visual predators and filter feeders. In addition, pollutants, such as phosphorus, adsorb to sediment particles and are transported to streams through erosion processes.

3.2.3 Habitat Alteration

The relative lack of riparian vegetation along sections of these streams was considered to be a potential factor affecting the benthic community. Minimal riparian vegetation was observed in specific areas during the TMDL field visit. In these watersheds, riparian areas are often used to grow crops and as pasture for livestock. Riparian areas perform many functions that are critical to the ecology of the streams that they border (Figure 3.1). Functional values include:

- Flood detention
- Nutrient cycling
- Plant roots stabilize banks and prevent erosion
- Wildlife habitat
- Canopy vegetation provides shading (decreases water temperature and increases baseflow through lower evaporation rates)

3.2.4 Toxic Pollutants

Toxic pollutants in the water column and sediment can result in acute and chronic effects on aquatic organisms. Increased mortality rates, reduced growth and fecundity, respiratory problems, tumors, deformities, and other consequences have been documented in toxicity studies of aquatic organisms. Degraded water quality conditions and other environmental stressors can lead to higher rates of incidence of these problems.

3.3 Monitoring Stations

There are 12 current and historical water quality sampling stations located in the Upper Blackwater River watershed; four are located on the Blackwater River mainstem (upper and middle segments) and eight are located on tributaries, including Green Creek (4AGCR000.01). Two stations (4ABWR045.80 and 4ABWR061.20) are long-term ambient water quality monitoring stations sampled regularly by DEQ; eight (4ABWR045.80, 4ABWR061.20, and 4ABNR000.40, 4ABNR003.21, 4ABNR001.53, 4ABSF002.34, 4ABWR049.73, 4AGCR000.01) are DEQ biological monitoring stations. These stations and others in the Blackwater River Watershed were sampled as part of a special study conducted from 1991 through 1995. Benthic community and habitat data are also collected at biomonitoring stations. Station locations are listed in Table 3.1 and shown in Figure 3.1.

Table 3.1 Monitoring stations for the Upper Blackwater River and Big Chestnut Creek watersheds

Station	Stream name	Description	Sample Type	Freq.	Period of Record Water quality	Period of Record Bio-monitoring
Upper Blackwater River Watershed						
4ABNR009.36	Blackwater R., N.F.	Rt. 643 Bridge north of Monta Vista	SS	Q	5/91–8/99	na
4ABNR004.56	Blackwater R., N.F.	Rt. 742 Bridge near Dillions Mill	SS	Q	5/91–5/03	na
4ABNR003.21	Blackwater R., N.F.	Rt. 739 Br. (Above Barnhardt Dairy)	B	SF	na	7/00-4/02
4ABNR001.53	Blackwater R., N.F.	Rt. 738 Br. (Below Barnhardt Dairy)	B	SF	na	7/00-4/02
4ABNR000.40	Blackwater R., N.F.	Rt. 740 Bridge S.W. of Retreat	B,SS	Q-SF	5/91–5/03	10/94-4/02
4AGCR000.01	Green Creek	Rt. 739 Bridge at Algoma	B,SS	Q-SF	5/91–5/03	10/94-10/00
4ABSF002.34	Blackwater R., S.F.	Callaway Elementary (Above school ditch)	B	SF	na	7/00-3/01
4ABSF001.15	Blackwater R., S.F.	Rt. 641 Bridge east of Callaway	SS	Q	5/91–6/01	na
4ABWR061.20	Blackwater R.	Rt. 641 Bridge	A,B,SS	Q-SF	4/89-5/03	10/94-4/02
4ABWR054.81	Blackwater R.	Rt. 734 Bridge	SS	Q	5/91-5/03	na
4ABWR049.73	Blackwater R.	Below Ford off of Rt. 732 (Blankenship property)	B		na	8/00 (n=1)
4ABWR045.80	Blackwater R.	Rt. 812 Bridge	A,B,SS	Q-SF	10/88-5/03	10/94-4/02
Reference						
4ACNT001.32	Big Chestnut Creek	Below Rt. 715 Br. (ambient station also)	A,B		10/96-5/01	9/00-5/02

Sample Type: A = Ambient; B = Biological; SS = Special Study
Freq.: Q = Quarterly; SF = Biomonitoring conducted Spring and Fall; B = Biweekly

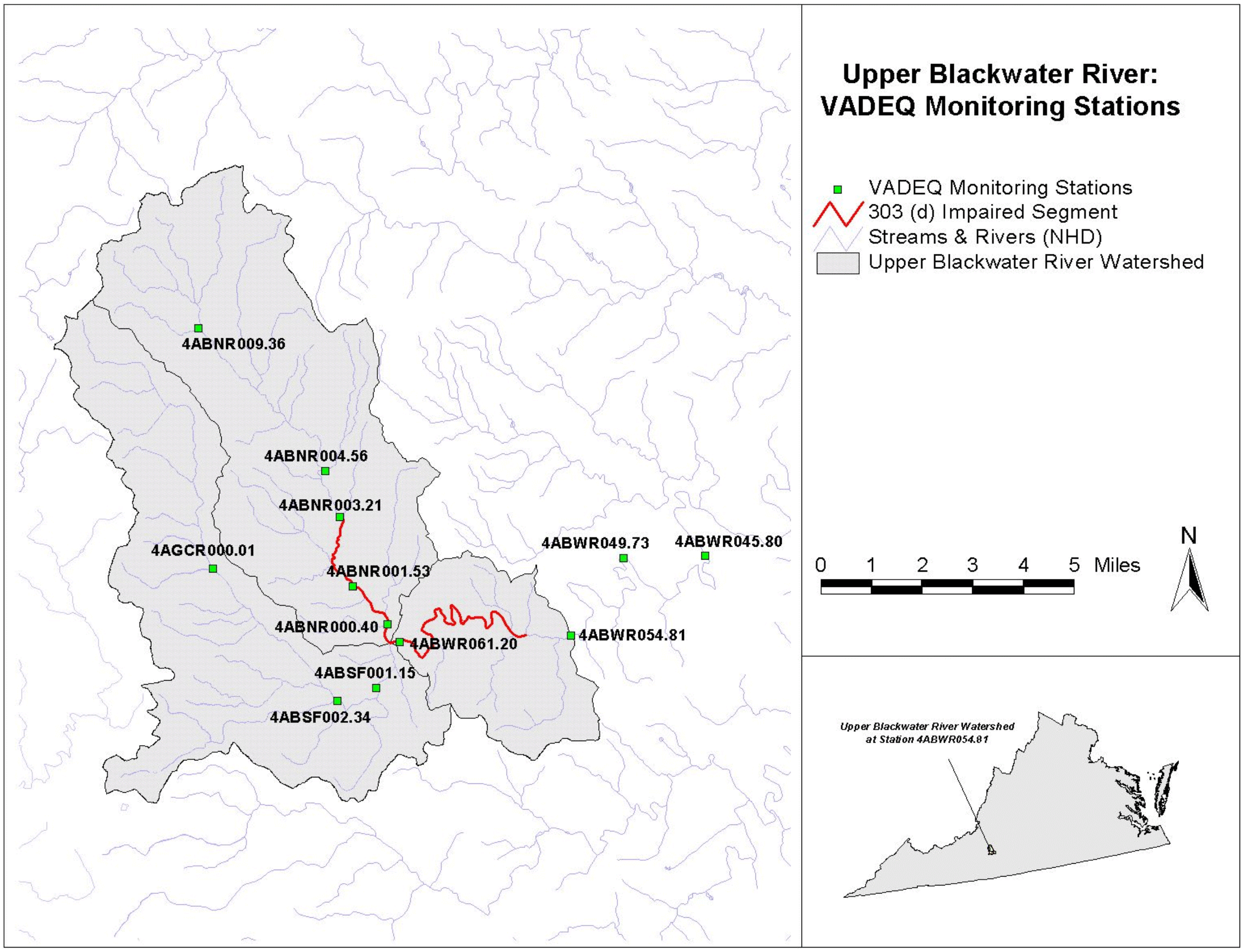


Figure 3.1 Location of Upper Blackwater River watershed monitoring stations

3.4 Monitoring Data Summary

3.4.1 Water Quality Monitoring Summary

The Upper Blackwater River and North Fork Blackwater River are designated as Class III, Nontidal Waters (Coastal and Piedmont Zones) in Virginia Water Quality Standards (9 VAC 25-260-50). The South Fork Blackwater River is designated as a Class V, Stockable Trout Water. Green Creek is designated as a Class VI, Natural Trout Water. Numeric criteria for dissolved oxygen (DO), pH, and maximum temperature for each stream class are shown in Table 3.2.

Table 3.2 Virginia numeric criteria for Class III, V, and VI waters

Stream Class	Dissolved Oxygen (mg/L)		pH (std units)	Max Temp (ºC)
	Min	Daily Avg		
III (Nontidal Waters - Coastal and Piedmont Zones	4.0	5.0	6.0 - 9.0	32
V (Stockable Trout Waters)	5.0	6.0	6.0 - 9.0	21
VI (Natural Trout Waters)	6.0	7.0	6.0 - 9.0	20

Water quality monitoring data were summarized to help determine general stream characteristics for Upper Blackwater and Big Chestnut Creek stations. Table 3.3 provides basic summary statistics for selected parameters and lists the period of record and the number of samples taken.

Table 3.3 General water quality data for Upper Blackwater River and Big Chestnut Creek ambient water quality monitoring and special study stations

Station		Selected Water Quality Parameters															
		SAMP DATE	TEMP	DO	PH	COND	TURB FTU	BOD5	TSS	NH3	NO2	NO3	NO2 NO3	TKN	P_ TOTAL	PO4	N/P
BNR00936	Valid N	115	114	102	112	114	38	2	112	111	111	111	111	111	111	111	111
	Mean		17.35	8.8	7.6	46.75	6.33	2	35.1	0.04	0.01	0.3	0.32	0.36	0.05	0.03	15.86
	Median		18.05	8.59	7.6	49	5.5	2	9	0.04	0.01	0.28	0.29	0.3	0.04	0.03	14.5
	Minimum	5/20/1991	9.3	7.34	6.02	5	1.88	2	1	0.04	0.01	0.1	0.11	0.1	0.02	0.01	1.7
	Maximum	8/26/1999	23.5	11.6	8.66	85	29	2	2700	0.12	0.05	0.59	0.6	3.5	0.8	0.09	55.25
BNR00456	Valid N	125	124	111	120	123	49	2	121	122	122	122	122	122	122	122	122
	Mean		18.23	9.08	7.84	55.75	5.65	2	8.58	0.04	0.01	0.33	0.34	0.36	0.06	0.03	14.7
	Median		19.15	8.71	7.86	58	4	2	6	0.04	0.01	0.33	0.34	0.3	0.05	0.03	14.17
	Minimum	5/20/1991	1.1	7.23	7.04	12	1.7	2	2	0.04	0.01	0.04	0.05	0.1	0.01	0.01	1.5
	Maximum	5/27/2003	26	14.6	8.9	90	35	2	74	0.08	0.05	0.67	0.68	1.3	0.4	0.11	32

Station		Selected Water Quality Parameters															
		SAMP DATE	TEMP	DO	PH	COND	TURB FTU	BOD5	TSS	NH3	NO2	NO3	NO2 NO3	TKN	P_ TOTAL	PO4	N/P
BNR00040	Valid N	163	147	133	146	146	49	2	124	142	142	142	142	142	142	142	142
	Mean		18.18	8.81	7.62	64.91	11.7	2	18.1	0.1	0.02	0.47	0.49	0.72	0.11	0.06	13.15
	Median		19.5	8.52	7.58	66.5	8.1	2	10	0.06	0.01	0.445	0.46	0.6	0.09	0.05	12
	Minimum	5/20/1991	0.4	4.35	6.38	20	0.54	2	3	0.04	0.01	0.13	0.14	0.1	0.03	0.02	1.538
	Maximum	5/27/2003	28.9	14.6	9.14	129	58	2	391	0.9	0.06	1.34	1.35	3.5	0.8	0.35	34
GCR00001	Valid N	141	128	113	126	128	49	2	124	123	122	123	122	123	123	123	122
	Mean		16.85	9.1	7.65	50.5	6.45	2	11.6	0.05	0.01	0.3	0.31	0.32	0.06	0.03	13.18
	Median		17.8	8.82	7.65	51	5.5	2	9.5	0.04	0.01	0.29	0.3	0.3	0.05	0.03	12
	Minimum	5/20/1991	1.3	7.11	6.36	11	0.7	2	1	0.04	0.01	0.07	0.08	0.1	0.02	0.01	1.54
	Maximum	5/27/2003	24.5	13.6	9.14	170	19.3	2	87	0.6	0.05	0.77	0.78	0.9	0.5	0.08	49.33
BSF00115	Valid N	138	135	121	132	134	38	2	115	132	132	132	132	132	132	132	132
	Mean		17.29	9.15	7.68	52.97	9.06	2	13.3	0.05	0.01	0.55	0.56	0.37	0.07	0.04	17.63
	Median		18.4	8.81	7.72	55.5	6.45	2	8	0.04	0.01	0.52	0.53	0.3	0.05	0.03	16.71
	Minimum	5/20/1991	0.6	6.95	6.35	15	2.6	2	3	0.04	0.01	0.23	0.24	0.1	0.02	0.01	2
	Maximum	6/25/2001	25.4	13.8	9.09	79	35	2	307	0.19	0.05	1.26	1.27	2.5	0.5	0.15	57
BWR06120	Valid N	181	167	146	164	165	69	29	146	145	145	145	145	145	145	145	145
	Mean		16.8	9.29	7.69	57.93	10.35	2.07	14.7	0.06	0.01	0.62	0.63	0.47	0.09	0.04	16.84
	Median		18.5	9	7.67	58.1	7	2	8	0.04	0.01	0.53	0.54	0.4	0.07	0.04	14.14
	Minimum	4/17/1989	0.3	5.84	6.27	19	1.9	1	3	0.04	0.01	0.25	0.26	0.1	0.03	0.01	1.82
	Maximum	5/27/2003	28.4	14.1	9	95	56	3	328	0.48	0.06	10.75	10.76	2.9	0.6	0.19	271.5
BWR05481	Valid N	148	147	130	146	146	49	2	127	142	142	142	142	142	141	142	141
	Mean		17.79	8.83	7.58	61.86	20.8	5	18.5	0.07	0.02	0.6	0.61	0.58	0.11	0.05	14.94
	Median		19.1	8.45	7.6	62	10.8	5	10	0.05	0.01	0.57	0.59	0.5	0.08	0.05	13.92
	Minimum	5/29/1991	0.2	6.33	5.93	20	2.4	2	3	0.03	0.01	0.14	0.15	0.04	0.03	0.01	1.42
	Maximum	5/27/2003	25.2	14.1	9.05	109	170	8	210	0.66	0.08	1.32	1.33	5	1.5	0.51	45.33
BWR04580	Valid N	185	170	147	168	167	74	29	152	151	151	151	151	151	151	151	151
	Mean		17.44	8.93	7.62	64.26	33.56	2.41	25.6	0.07	0.02	0.63	0.64	0.56	0.12	0.06	14.58
	Median		18.45	8.5	7.63	65	9.5	2	9	0.04	0.01	0.61	0.63	0.4	0.08	0.05	13.11
	Minimum	10/25/1988	0.4	5.6	5.86	26	2.1	2	3	0.04	0.01	0.09	0.1	0.1	0.02	0.01	2.68
	Maximum	5/27/2003	25.3	14.1	9.02	118	870	5	875	0.65	0.2	1.3	1.32	3.8	1.7	0.88	50.5
CNT00132	Valid N	18	18	18	17	18	15	15	15	15	15	15	15	15	15	15	15
	Mean		13.31	9.62	7.89	48	8.66	2.2	4.73	0.05	0.01	0.17	0.18	0.24	0.05	0.02	16.27
	Median		14.95	9.2	7.9	50	7.27	2	4	0.04	0.01	0.17	0.18	0.2	0.02	0.02	20
	Minimum	10/15/1996	1.4	7.4	7	32	2.7	1	3	0.04	0.01	0.04	0.05	0.1	0.01	0.01	1.5
	Maximum	5/7/2001	23.6	13.5	8.87	70	30	5	15	0.12	0.06	0.44	0.45	0.6	0.1	0.04	36

3.4.2 Water Quality Summary Plots

Selected parameters were plotted to examine spatial trends and to compare impaired and reference stream conditions (Figures 3.2 through 3.27). Box-whisker and time-series plots are shown for each parameter. Box-whisker plots display the median value, 25^{th} and 75^{th} percentile values, the non-outlier minimum/maximum range, outliers, and extreme values. The box shows the range from the 25^{th} percentile to the 75^{th} percentile of the dataset. Within the box, the median, or 50^{th} percentile value, is displayed as a point. Whiskers show the range from the non-outlier minimum value (often 0) to the non-outlier maximum value. For graphical display purposes, not all outlier and extreme values are shown in these figures. Time-series plots show all the individual observations over the period of record for each station. For Blackwater River special study stations, a majority of the data were collected during the summer months from 1991 through 1995.

Dissolved Oxygen

Dissolved oxygen (DO) levels for Upper Blackwater watershed stations were lower than in the reference stream, Big Chestnut Creek (Figures 3.2 and 3.3). AWQM and special study DO data collected at each station were compared to the daily average and minimum DO criteria listed in Virginia Water Quality Standards to help determine if DO conditions are considered to be a primary cause of the benthic impairment. All median DO levels were above 5.0 mg/L, the daily average criteria for Class III streams. The lowest DO concentration was recorded at station 4ABNR000.40 on the North Fork Blackwater River.

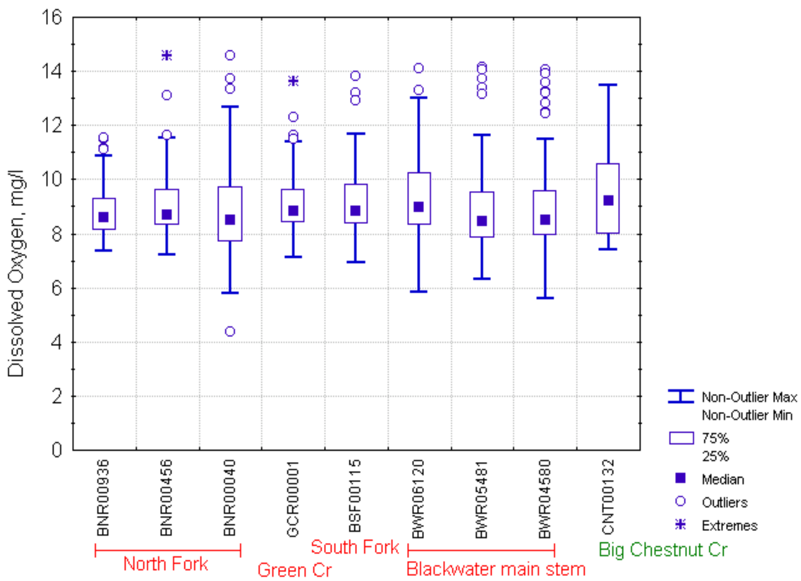


Figure 3.2 Stream comparison of DO data

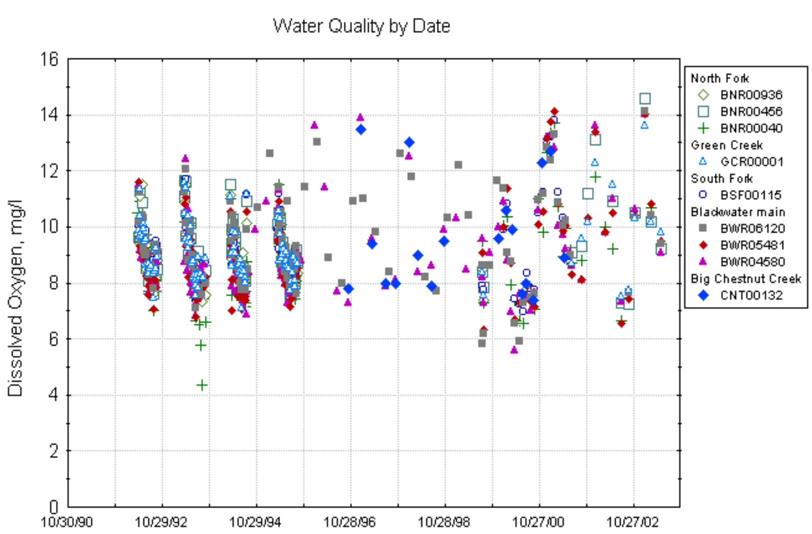


Figure 3.3 Time-series DO data

Water Temperature

Big Chestnut Creek (Station CNT001.32) had the lowest recorded temperature values (Figures 3.4 and 3.5). Stations BNR000.40 and BWR061.20 had the highest non-outlier maximum values for the period of record. Temperature exceedances were noted for Green Creek and South Fork Blackwater River, due to the more stringent criteria designated for Class V and VI streams. These streams were listed as impaired for temperature on the 2002 303(d) list, due to natural conditions.

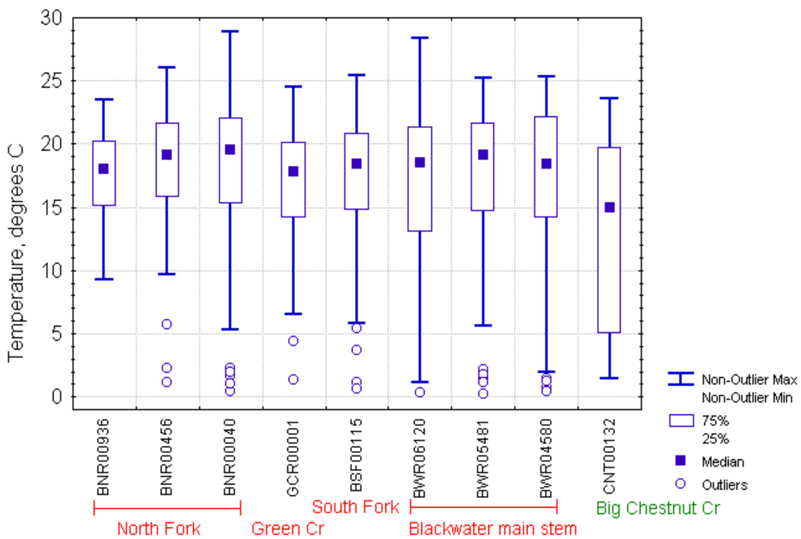


Figure 3.4 Stream comparison of temperature data

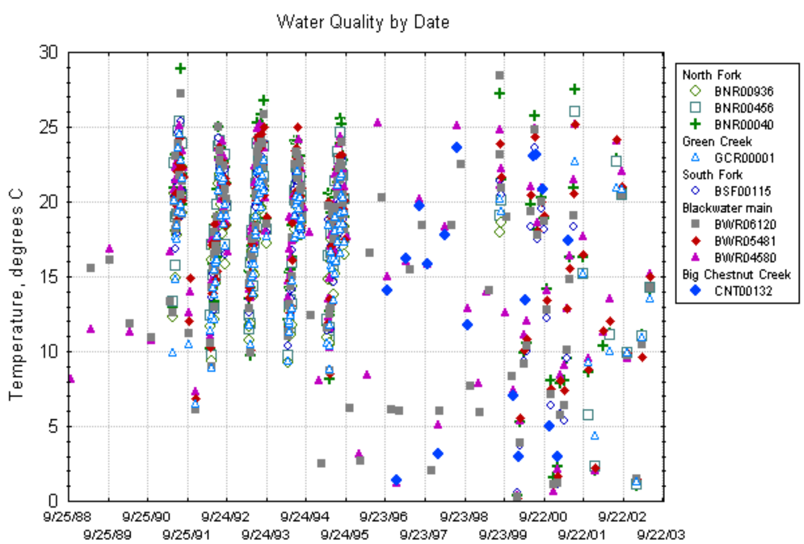


Figure 3.5 Time-series temperature data

pH

pH values are shown in Figures 3.6 and 3.7. Several Upper Blackwater watershed stations had pH values outside the acceptable range of 6.0 to 9.0 standard units for these streams. There were not enough exceedances over the period of record to list these streams as impaired for pH.

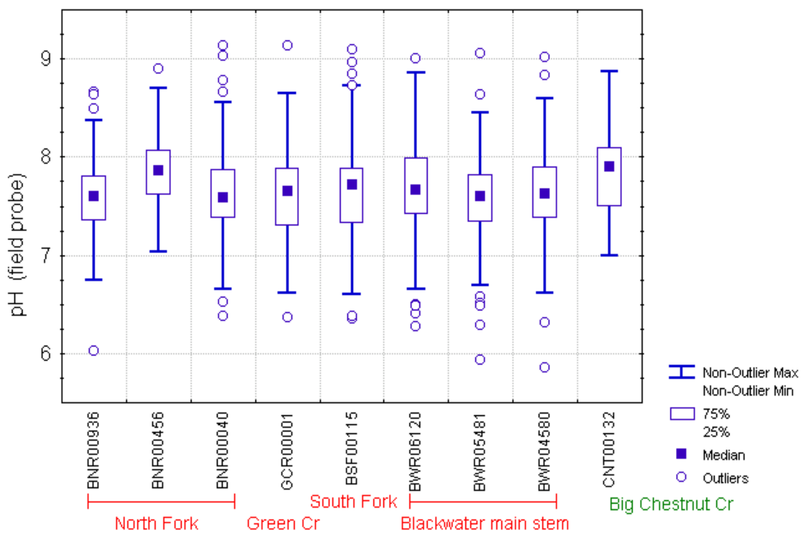


Figure 3.6 Stream comparison of pH data

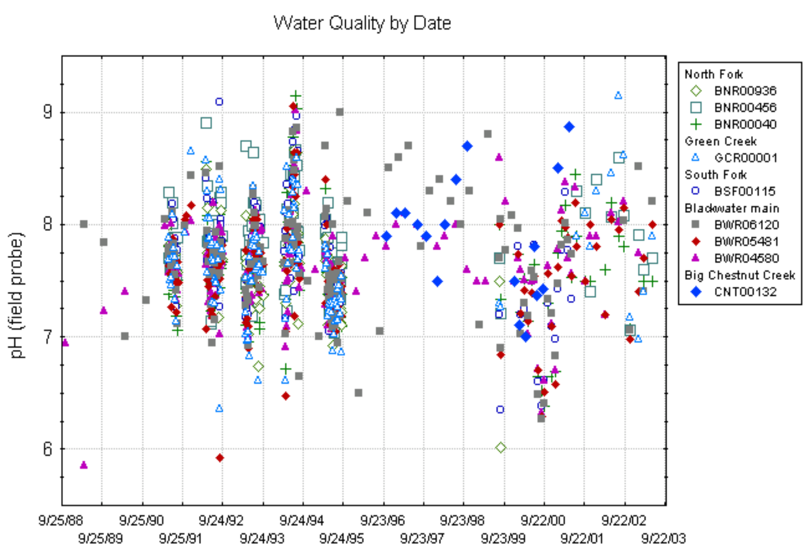


Figure 3.7 Time-series pH data

Conductivity (Specific Conductance)

High conductivity values are shown for several Upper Blackwater watershed stations (Figures 3.8 and 3.9). BNR000.40 and BWR045.80 had the highest median and non-outlier maximum conductivity values for the period of record. Big Chestnut Creek, CNT001.32, recorded the lowest conductivity measurements.

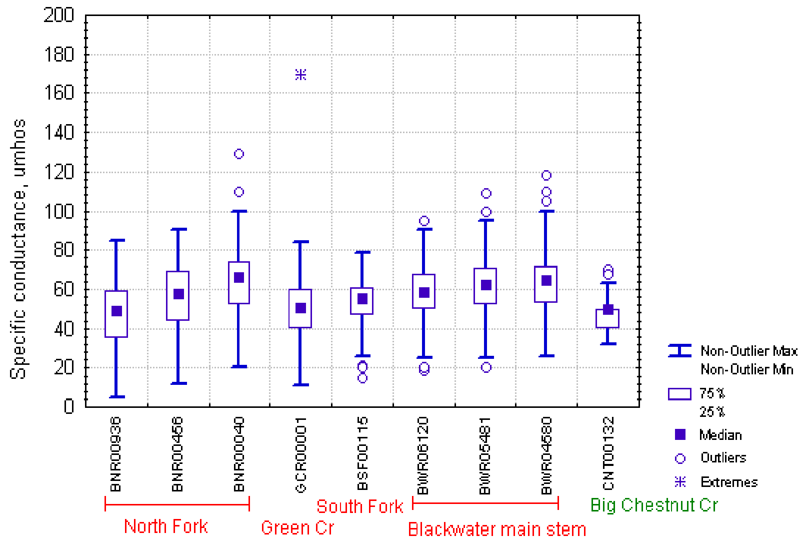


Figure 3.8 Stream comparison of conductivity data

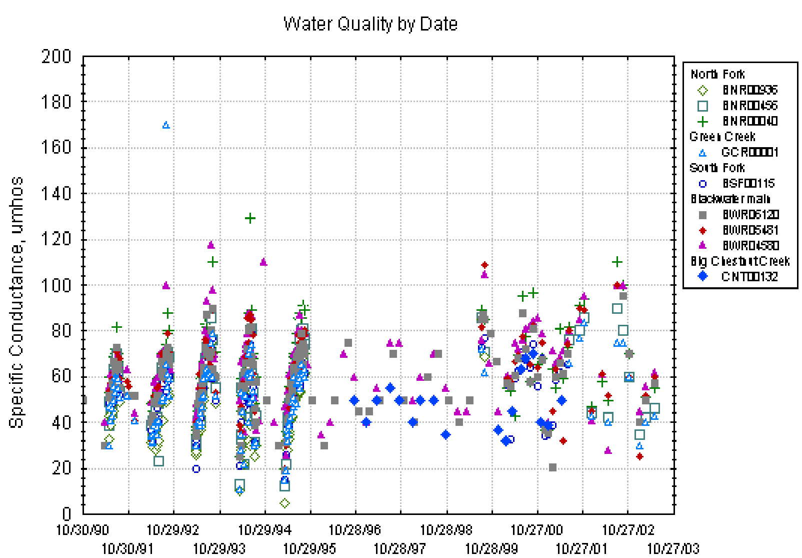


Figure 3.9 Time-series conductivity data

Phosphorus

Phosphorus is generally present in waters and wastewaters in different species of soluble (dissolved) and insoluble (particulate or suspended) phosphates, including inorganic (ortho- and condensed) phosphates and organic phosphates. Major sources of phosphorus include detergents, fertilizers, domestic sewage, and agricultural runoff. Figures 3.10 through 3.13 show total phosphorus (TP) and ortho-phosphate (OP) concentrations in the Upper Blackwater River and Big Chestnut Creek watersheds. Median TP and OP concentrations were greater for the Upper Blackwater stations as compared to Big Chestnut Creek. The highest TP and OP concentrations were recorded at station BNR000.40 (North Fork Blackwater River) followed by the Blackwater mainstem stations (BWR045.80, BWR054.81, and BWR061.20). Big Chestnut Creek had the lowest median TP and OP concentrations and non-outlier minimum values.

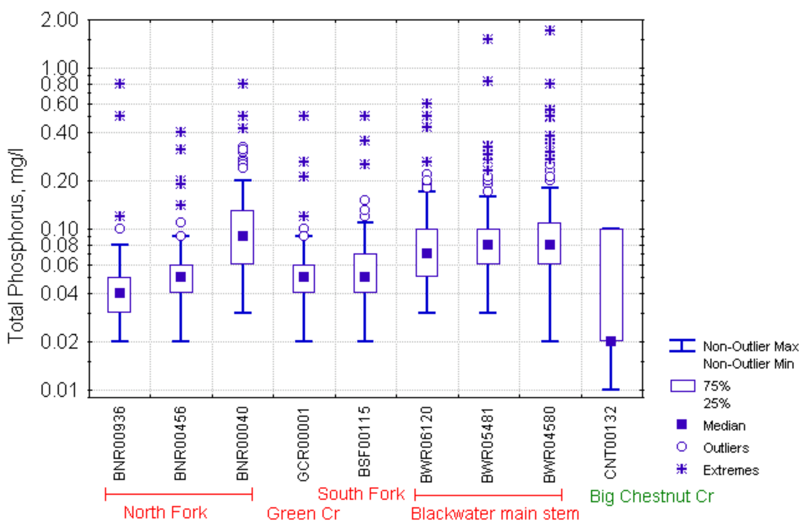


Figure 3.10 Stream comparison of total phosphorus data

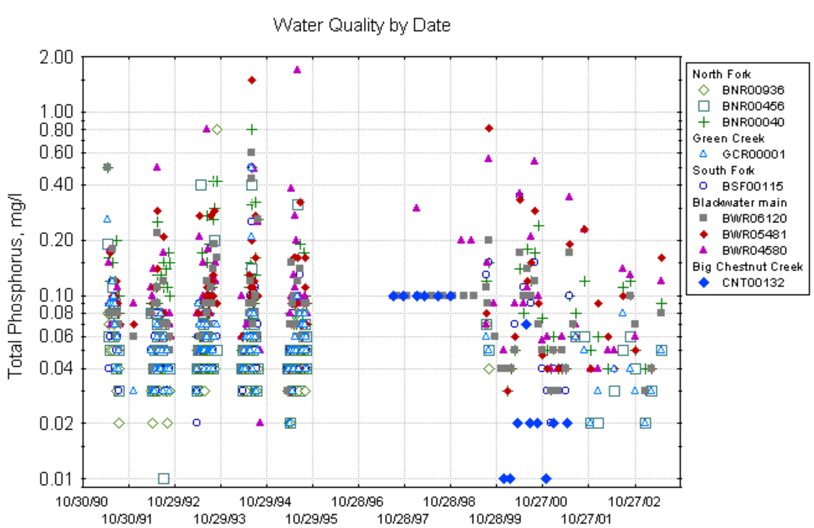


Figure 3.11 Time-series total phosphorus data

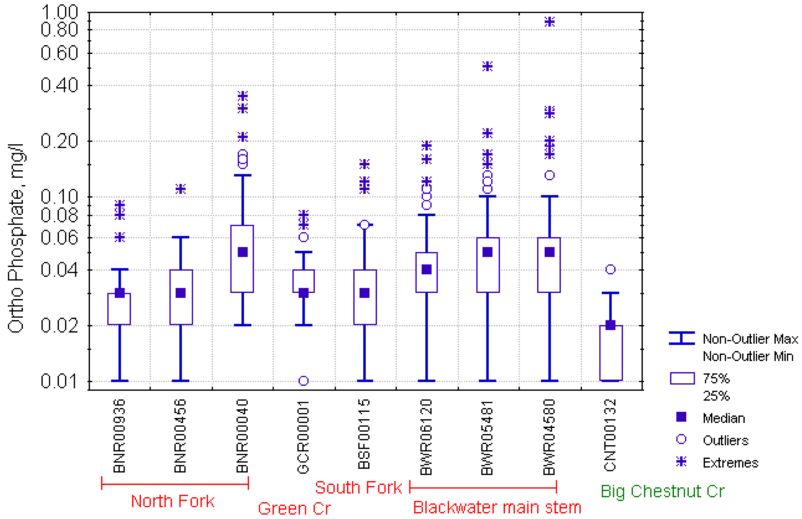


Figure 3.12 Stream comparison of orthophosphate data

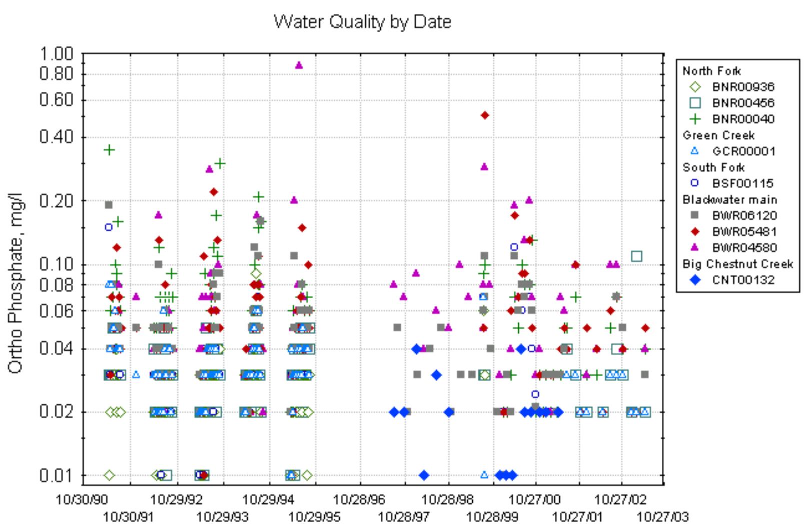


Figure 3.13 Time-series orthophosphate data

Nitrogen

Major sources of nitrogen include municipal and industrial wastewater, septic tanks, feed lot discharges, animal wastes, runoff from fertilized agricultural field and lawns, and discharges from car exhausts. Nitrogen species data are shown in Figures 3.14 through 3.21. These data indicate elevated levels of nitrogen concentrations in Upper Blackwater River watershed streams as compared to the reference condition. Nitrogen species data indicate a similar trend among stations, as compared to the TP and OP data shown in the previous section. Figures 3.14 and 3.15 show the distribution of nitrate concentrations recorded at Upper Blackwater and Big Chestnut Creek monitoring stations. The median nitrate concentration for the Big Chestnut Creek station was approximately 0.15 mg/L. By contrast, three sampling stations (BNR000.40, BWR054.81, and BWR045.80) recorded median nitrate concentrations above 0.5 mg/L.

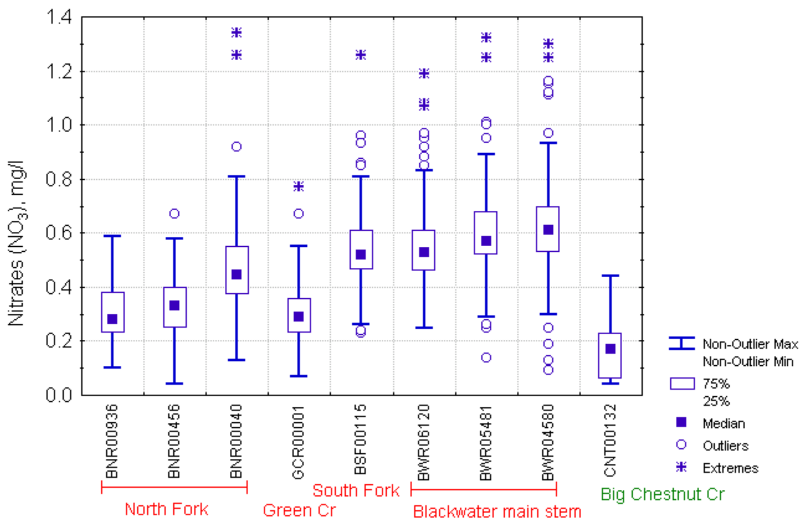


Figure 3.14 Stream comparison of nitrate data

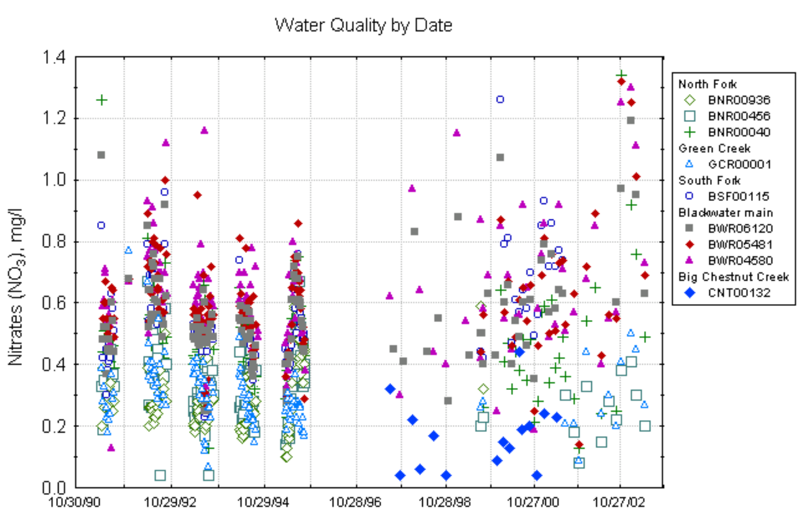


Figure 3.15 Time-series nitrate data

Nitrite values recorded at Upper Blackwater River and Big Chestnut Creek sampling stations are shown in Figures 3.16 and 3.17. Stations BNR000.40 and BWR054.81 recorded the highest 75th percentile and non-outlier maximum concentrations.

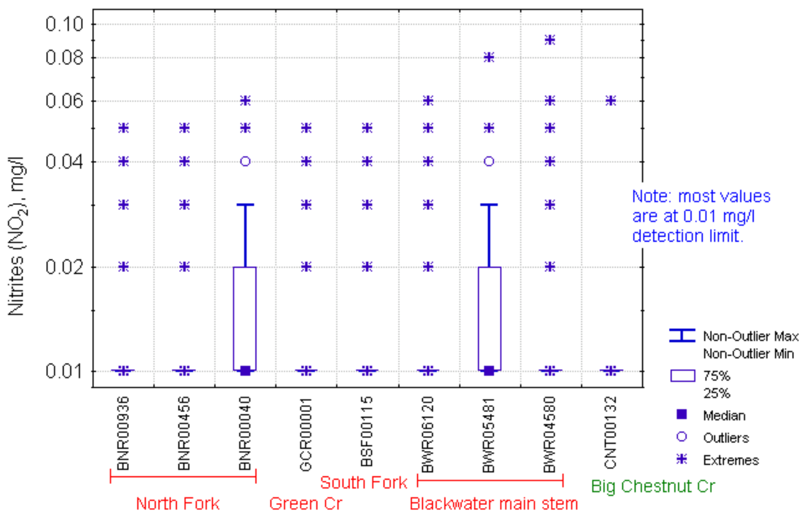


Figure 3.16 Stream comparison of nitrite data

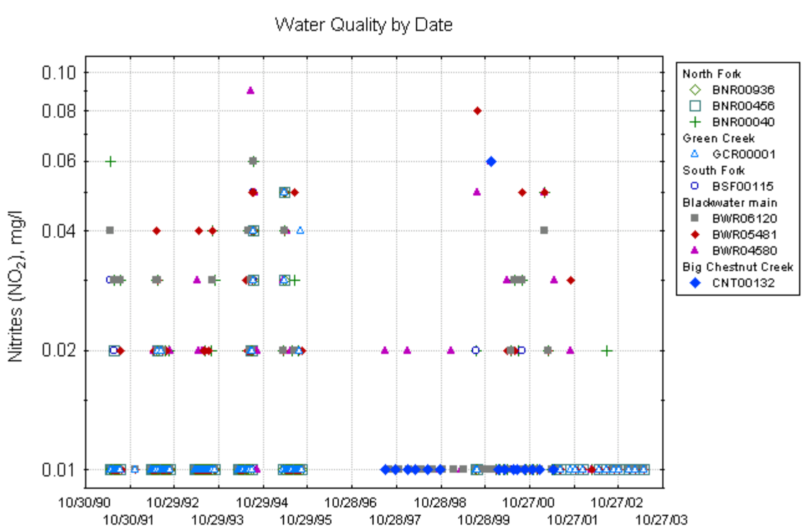


Figure 3.17 Time-series nitrite data

TKN values for Upper Blackwater River and Big Chestnut Creek stations are shown in Figures 3.18 and 3.19. TKN concentrations for Big Chestnut Creek were lower than those recorded for Upper Blackwater River stations. Station BNR000.40 recorded the highest TKN concentrations for the period of record.

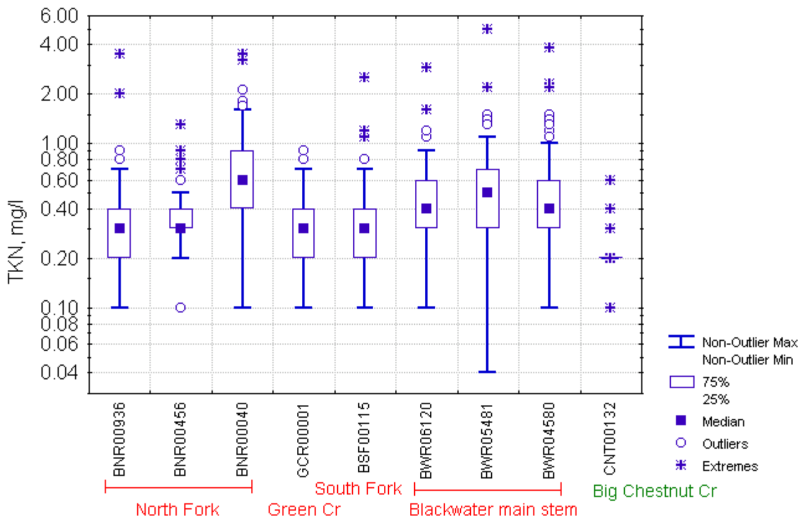


Figure 3.18 Stream comparison of TKN data

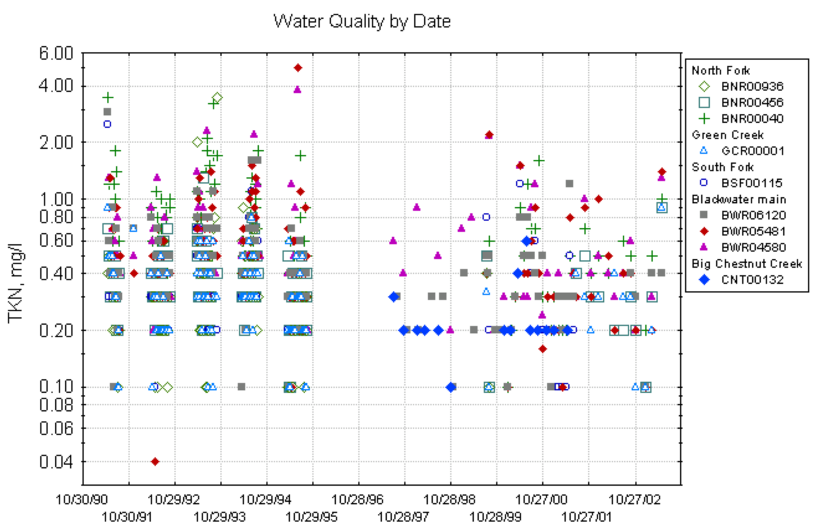


Figure 3.19 Time-series TKN data

Ammonia is a critical component of the nitrogen cycle. At high concentrations, ammonia is toxic to aquatic life, depending on instream pH and temperature levels. In general, higher temperature and pH levels increase the toxicity of ammonia. Virginia Water Quality Standards (9 VAC 25-260-140) list acute and chronic criteria for ammonia. Figures 3.20 and 3.21 show total ammonia (NH3+NH4) values for Upper Blackwater River and Big Chestnut Creek stations. Elevated concentrations were observed for Upper Blackwater mainstem and North Fork Blackwater stations. These data suggest possible acute or chronic effects to aquatic life if levels consistently exceed established water quality criteria. These data were compared to acute and chronic ammonia criteria in Section 3.5

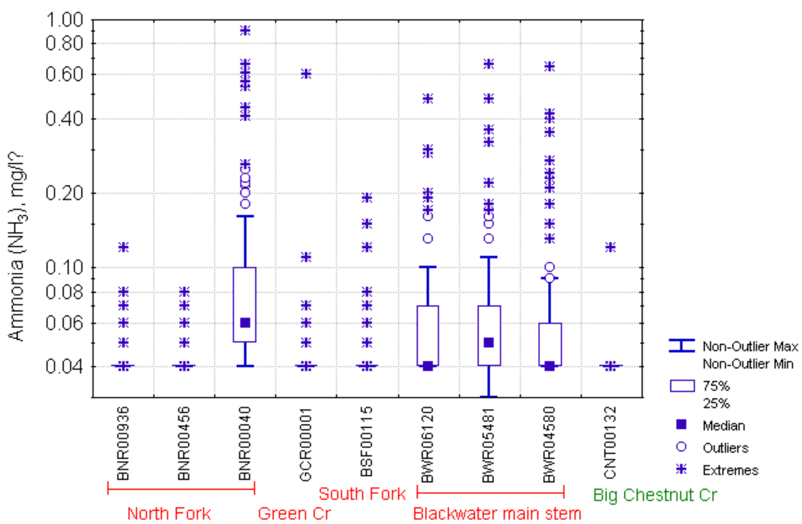


Figure 3.20 Stream comparison of ammonia data

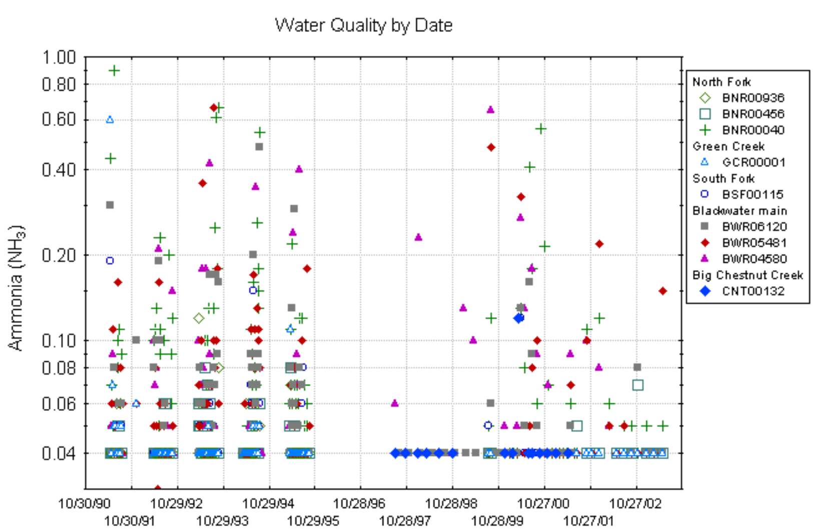


Figure 3.21 Time-series ammonia data

Nitrogen to Phosphorus ratios (N:P)

Based on available water quality data, nitrogen to phosphorus ratios were calculated for each water quality station to determine the limiting nutrient in the Blackwater River watershed. An N:P ratio greater than 10 typically indicates a phosphorus limited system; while a ratio of less than 10 indicates a nitrogen limited system. N/P ratios were calculated for each station (Figures 3.22 and 3.23). For all stations, median N:P ratios are greater than 10, which indicates phosphorus is the limiting nutrient.

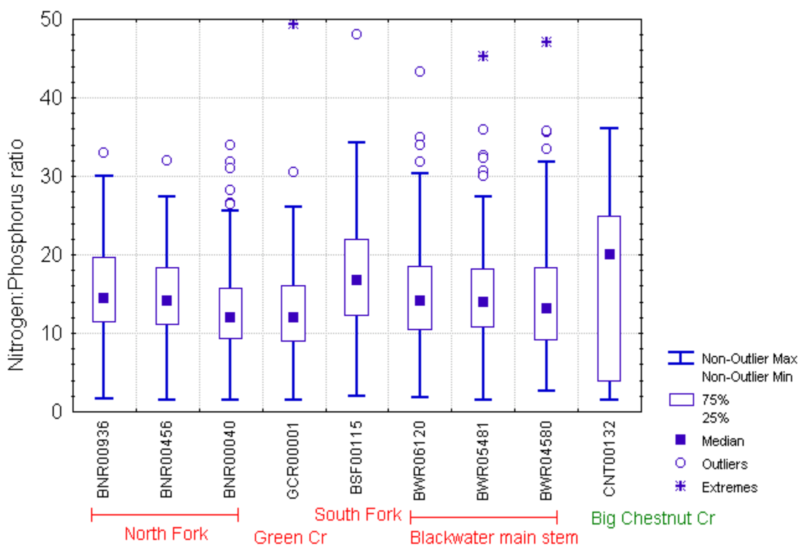


Figure 3.22 Stream comparison of N:P ratios

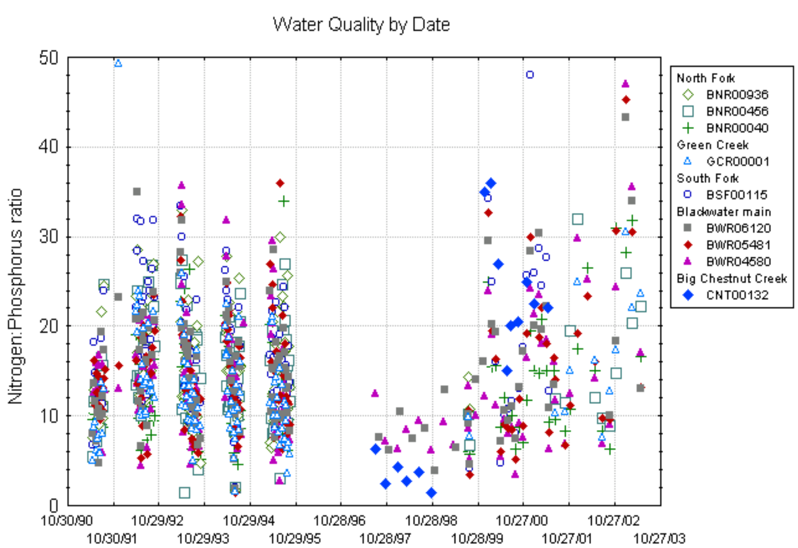


Figure 3.23 Time-series N:P ratios

Total Suspended Solids and Turbidity

Total suspended solids (TSS) and turbidity data were used to help examine possible sedimentation impacts on the benthic macroinvertebrate community (Figures 3.24 through 3.27). TSS data for Big Chestnut Creek were lower than TSS data recorded for Upper Blackwater River watershed stations (Figures 3.24 and 3.25). In general, the North Fork Blackwater station (BNR000.40) and Blackwater mainstem stations recorded the highest TSS levels during the period of record. Median TSS concentrations were highest at Stations BNR000.40 and BWR054.81. The maximum TSS concentration recorded for Big Chestnut Creek was approximately 5.0 mg/L.

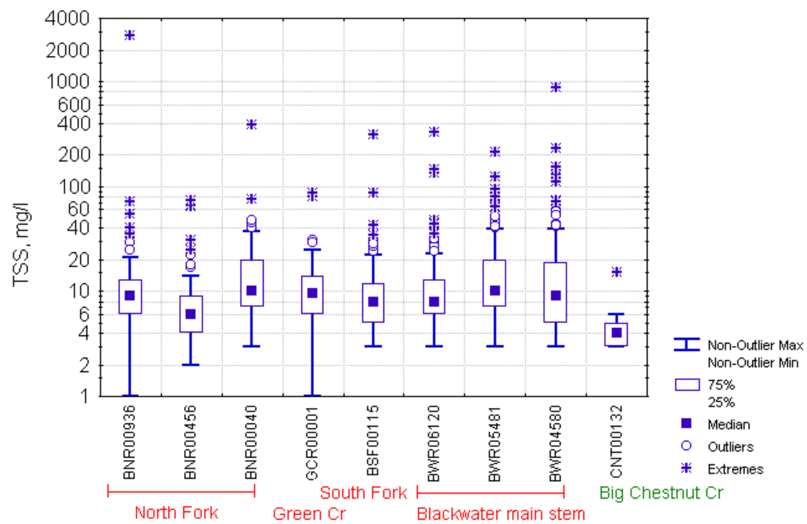


Figure 3.24 Stream comparison of TSS data

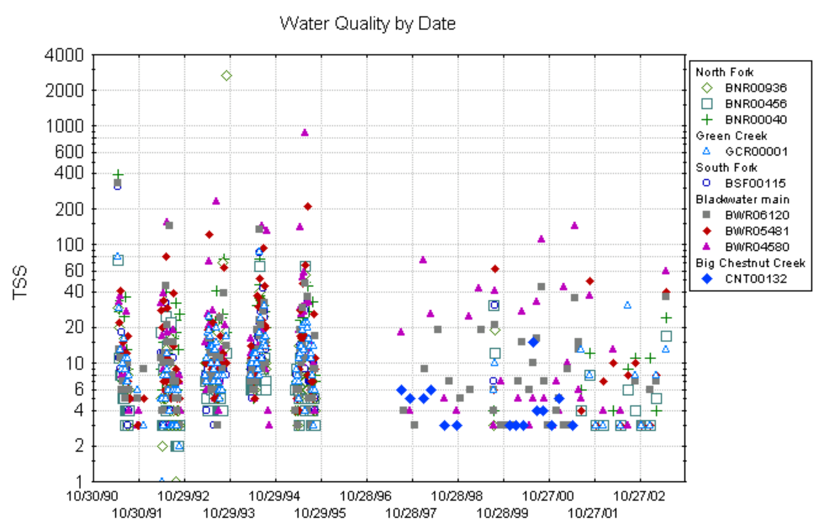


Figure 3.25 Time-series TSS data

Turbidity data for Upper Blackwater River and Big Chestnut Creek stations are shown in Figures 3.26 and 3.27. Stations BWR054.81 and BWR045.80 had the highest median turbidity values for the period of record. In general, the lowest turbidity concentrations were measured in the upper portion of the North Fork Blackwater River (BNR004.56 and BNR009.36), Green Creek, and Big Chestnut Creek.

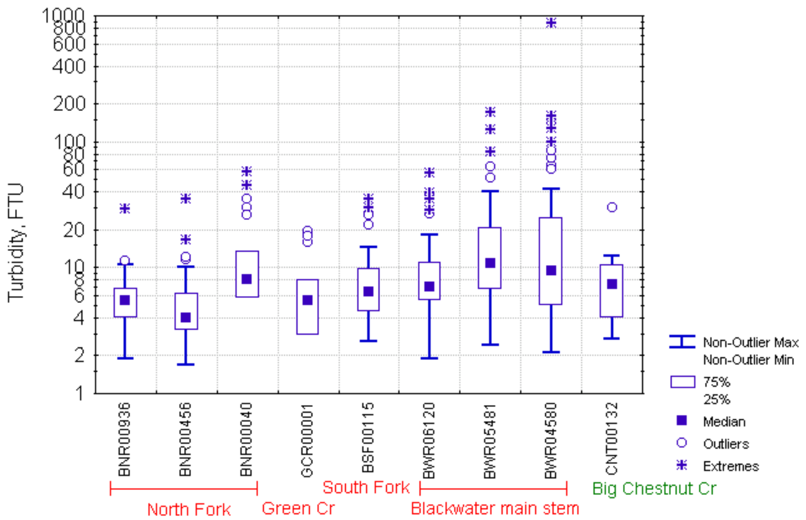


Figure 3.26 Stream comparison of turbidity data

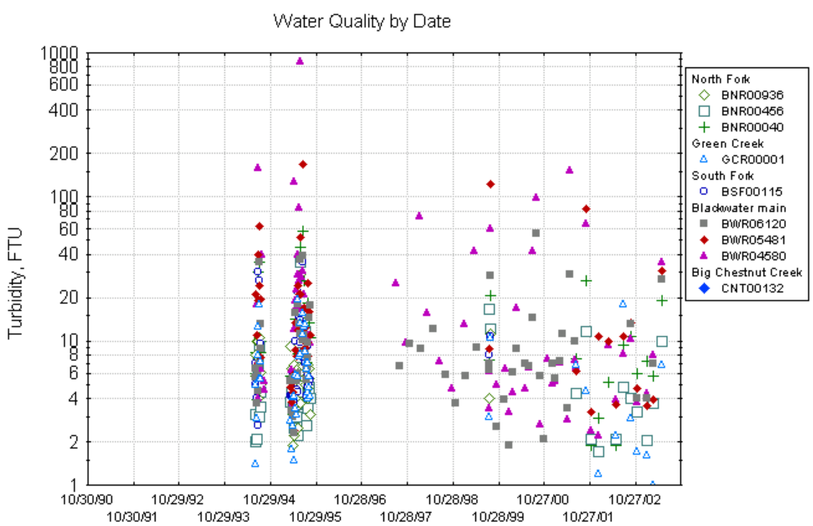
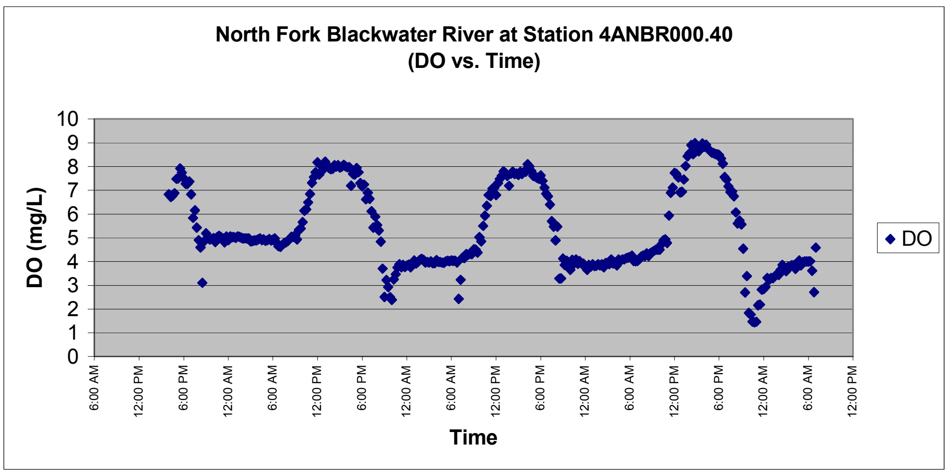


Figure 3.27 Time-series turbidity data

3.4.3 Diel DO Analysis

Primary producers (algae and macrophytes) produce oxygen during the day through photosynthesis and use oxygen at night through respiration. This diel photosynthesis/respiration cycle results in higher DO concentrations during the day and lower concentrations at night.

To further investigate the potential for low DO concentrations, 24-hour dissolved oxygen monitoring was conducted at two locations in September 2002 (Figure 3.28). VADEQ collected these data during early fall, low-flow conditions. Low dissolved oxygen conditions, which stress the benthic macroinvertebrate community, typically occur in the late summer/early fall when stream temperatures are their warmest and streamflow is lower. These conditions provide information on dissolved oxygen levels that may occur during these critical periods when algal blooms can cause low DO levels . Station 4ABWR061.20 shows a relatively normal 24-hour DO pattern; whereas Station 4ABNR000.40 (North Fork Blackwater River) indicates depressed dissolved oxygen levels. Dissolved oxygen levels were below the daily average and minimum DO criteria. This condition is considered to be persistent enough to cause stress to the stream's biological community.



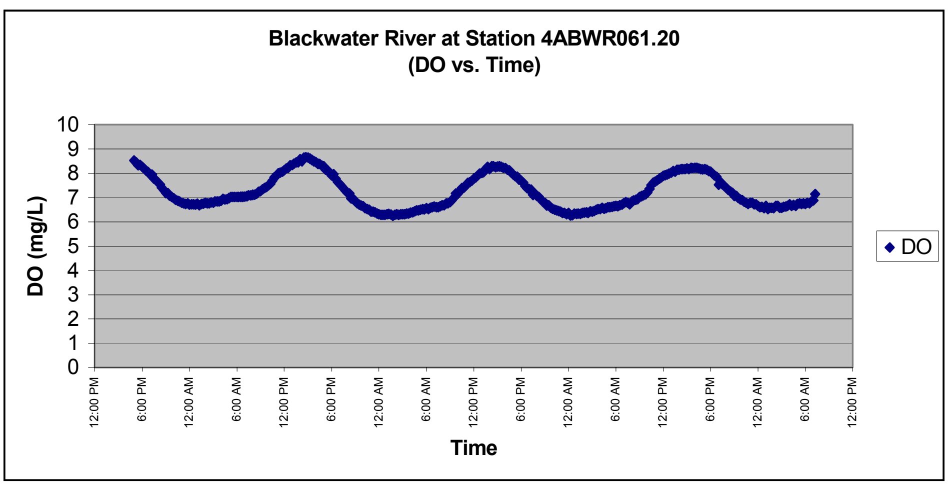


Figure 3.28 24-hour (diel) DO monitoring data

3.4.4 Rapid Bioassessment Protocol - Habitat Data

Rapid Bioassessment Protocol (RBP) habitat data for Upper Blackwater River and Big Chestnut Creek biomonitoring stations are shown in Figures 3.29 through 3.31. These data were used to examine possible sedimentation and other habitat impacts to the benthic community, along with the TSS and turbidity data discussed above. All habitat scores were evaluated and rated by observation (0-20, with higher scores being better). Overall, the median total habitat score for Big Chestnut Creek was greater than the majority of median total habitat scores recorded for Upper Blackwater stations located on impaired segments. However, recent data collected on Big Chestnut Creek may indicate a deterioration in habitat conditions as compared to previous sampling events.

Submerged materials and structures create epifaunal substrate and available cover for aquatic organisms. Logs, cobbles, gravel, and other materials provide habitat, niches and cover for aquatic organisms. The observed quality of epifaunal substrate/available cover in Big Chestnut Creek was generally better than conditions in the Upper Blackwater mainstem and North Fork Blackwater impaired segments (Figure 3.29). Green Creek had the highest epifaunal substrate/available cover scores, followed by Big Chestnut Creek.

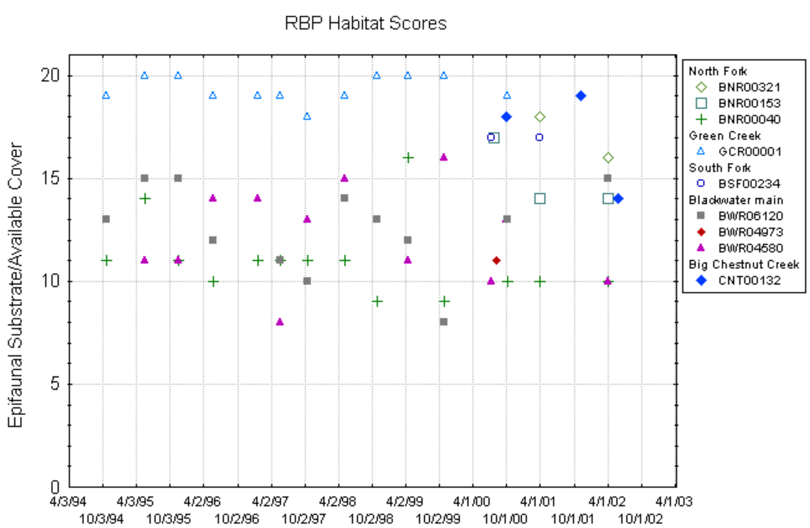


Figure 3.29 Epifaunal substrate/available cover values

Embeddedness measures the degree to which gravel, cobble and boulder particles of a stream bed are surrounded by fine sediment. A lower percentage of fine sediment particles is an indicator of more suitable stream habitat for benthic macroinvertebrates and fish spawning. The observed pool substrate scores for Big Chestnut Creek were greater than the majority of the embeddedness scores recorded for the Upper Blackwater River watershed impaired segments (Figure 3.30). Green Creek consistently recorded the highest embeddedness scores.

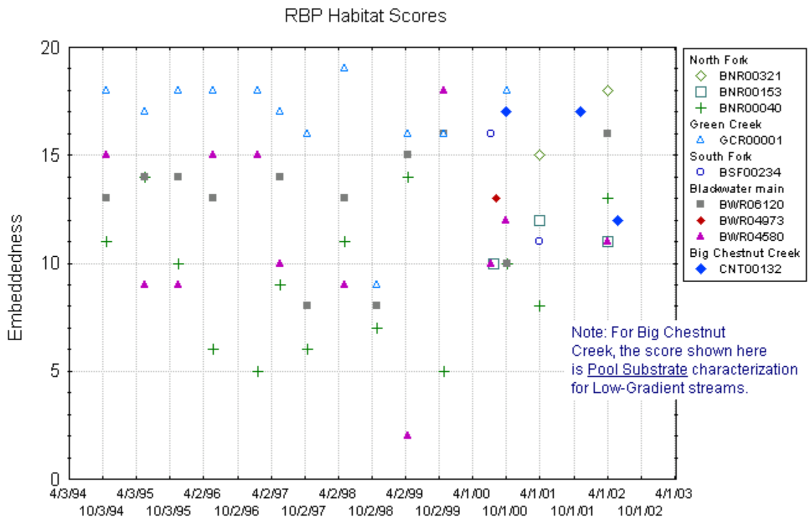


Figure 3.30 Embeddedness/pool substrate values

In larger streams and rivers the variability of velocity and depth of flow is related to the variety of aquatic habitat. The presence of four general categories of velocity and depth are indicators of the highest quality habitat. The absence of any of the four regimes is an indicator or a lower quality habitat. Figure 3.31 shows the observed velocity/depth regime values for each monitoring station. Green Creek and Big Chestnut Creek scores were generally higher than the velocity/depth regime scores for the other stations. The North Fork Blackwater River (Station BNR000.40) consistently had the lowest observed values.

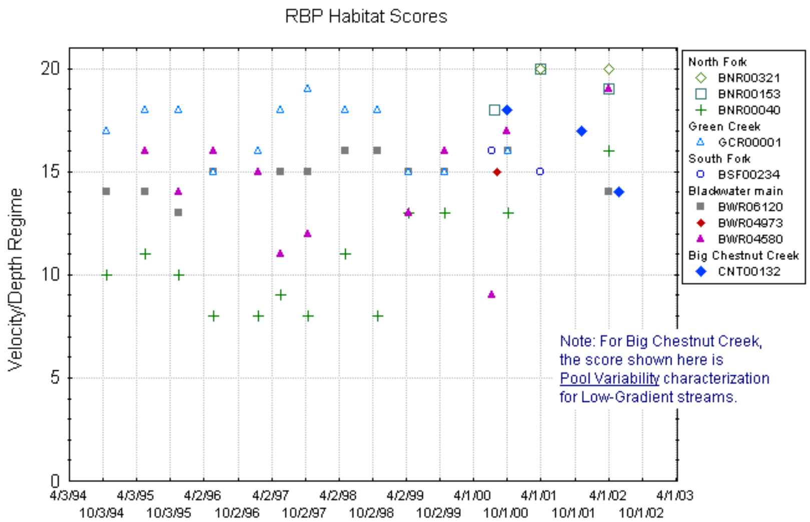


Figure 3.31 Velocity/depth regime values

Sediment deposition is a function of the sediment load, stream flow, and flow velocity of a stream. A slower rate of sediment deposition is an indicator of a healthier aquatic habitat. Observed sediment deposition rates are shown in Figure 3.32. The highest observed sediment deposition scores were recorded for Green Creek and Big Chestnut Creek. These data indicate better sediment habitat conditions at these stations. Stations BNR000.40 and BWR045.80 had the lowest scores.

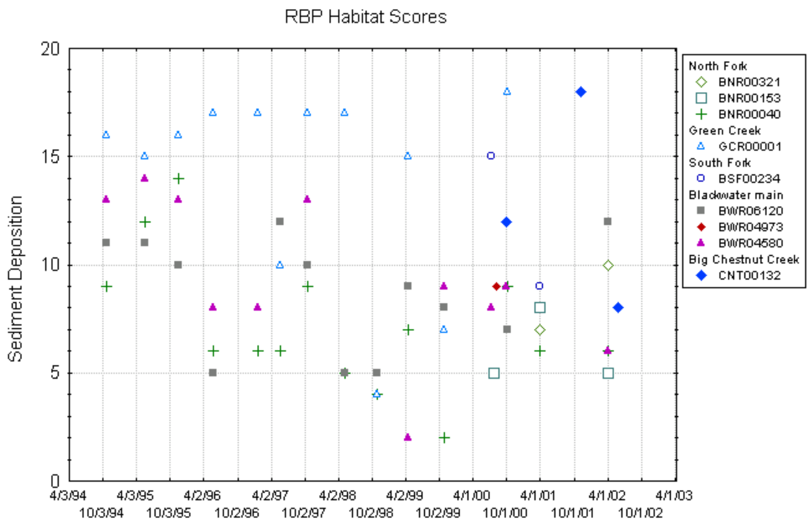


Figure 3.32 Sediment deposition values

Channel flow status is an assessment of stream flow. It relates the volume of water in a stream to its ability to provide and maintain a stable aquatic environment. Channel flow status scores are presented in Figure 3.33. South Fork Blackwater, Green Creek, and the upstream North Fork Blackwater stations had the highest channel flow status values. Big Chestnut Creek values were higher than those recorded for the Upper Blackwater and North Fork Blackwater impaired segments.

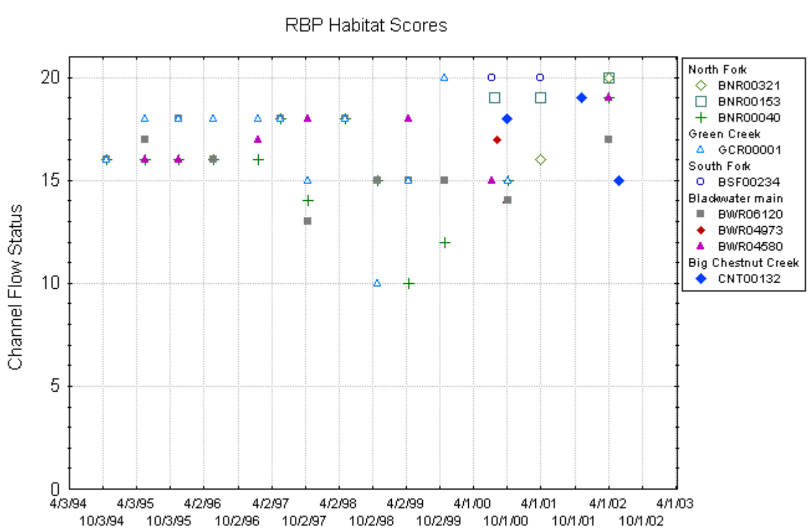


Figure 3.33 Channel flow status values

Stream channel alteration can result in a significant change to the flow regime. Flow regime changes can be linked to increased deposition rates, decreased sinuosity, and increased stream velocity. Channel alteration scores for these stations are presented in Figure 3.34. Stations BNR000.40 and BWR061.20 had the lowest observed channel alteration conditions, although these scores improved over time. Green Creek and Big Chestnut Creek values were consistently higher, on average.

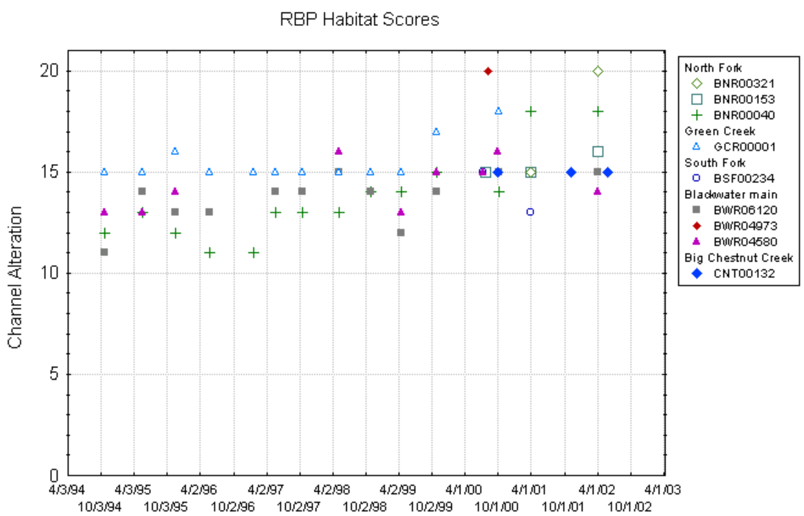


Figure 3.34 Channel alteration values

Riffles and bends provide more diverse habitat than straight or uniform depth streams. Observed values for the frequency of riffles and bends are presented in Figure 3.27. A higher frequency of these positive features was observed in Green Creek. Higher values were also recorded for Big Chestnut Creek, on two occasions. North Fork Blackwater and Upper Blackwater impaired segments had the lowest observed values.

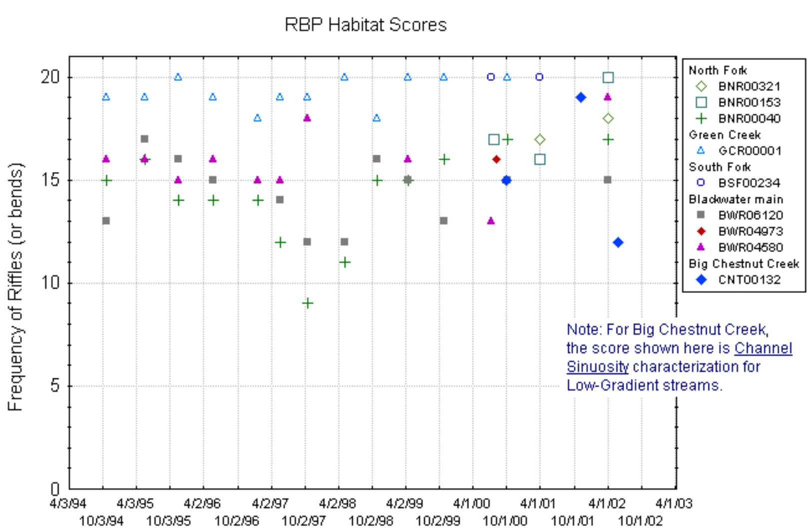


Figure 3.35 Frequency of riffles (or bends) values

Bank stability is rated by observing the existence of and/or potential for streambank erosion. Steeper banks are generally more susceptible to erosion and collapse and may not support stable vegetation. Bank stability observations for Upper Blackwater and Big Chestnut Creek stations are shown in Figure 3.36. The highest values were recorded for Green Creek and BNR003.21. Upper Blackwater and North Fork Blackwater impaired stations had the lowest observed bank stability condition.

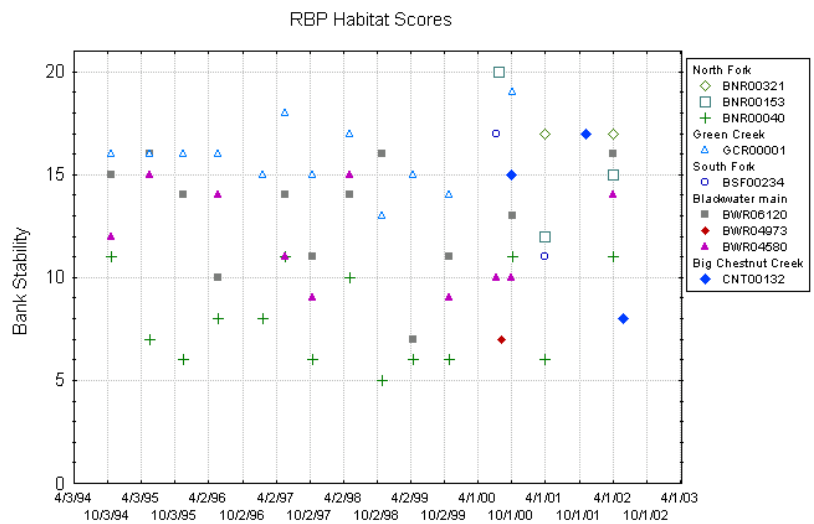


Figure 3.36 Bank stability values

Bank vegetative protection is an assessment of the density of vegetation and/or proportion of boulder, cobble, or gravel on a streambank that increases stability. This stability limits bank erosion, thereby reducing turbidity and sedimentation. The North Fork Blackwater impaired segment (BNR000.40) consistently had the lowest observed values for this parameter (Figure 3.37). The upper North Fork station, Green Creek, and Big Chestnut Creek recorded the highest scores.

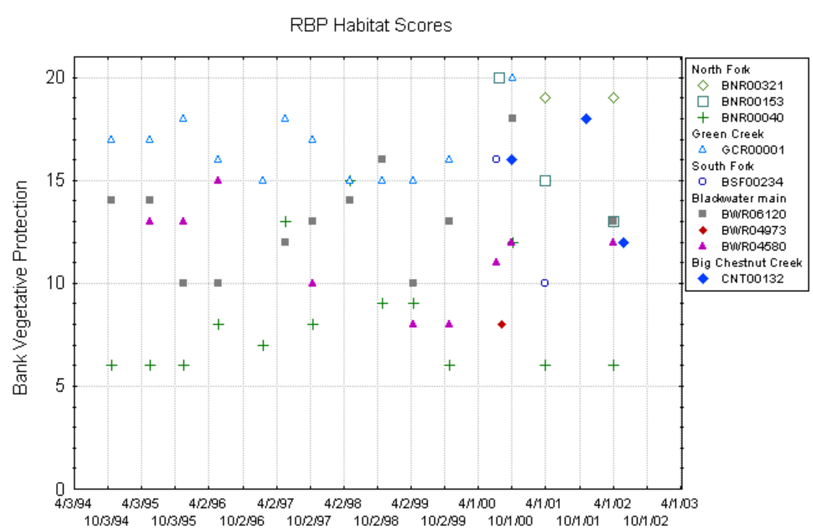


Figure 3.37 Bank vegetative protection values

Riparian vegetation provides shading, cover and refuge, and detrital input to the stream. Riparian vegetation scores for these stations are presented in Figure 3.38. Overall, Green Creek and Big Chestnut Creek had the highest observed values for riparian vegetation. North Fork Blackwater station BNR000.40 had the lowest observed scores, followed by BWR045.80 and BWR061.20 (Upper Blackwater impaired segment).

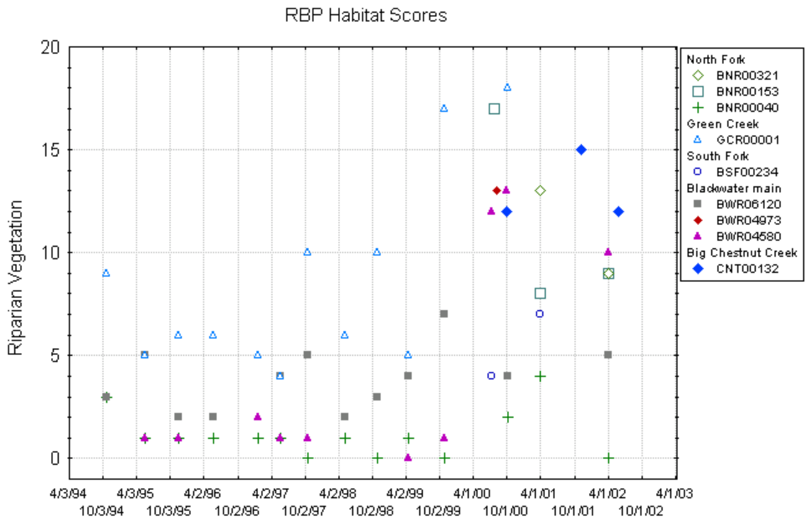


Figure 3.38 Riparian vegetation values

RBP total habitat scores are presented in Figure 3.39. Big Chestnut Creek total habitat scores exhibit some variability, but are higher than the majority of total habitat scores given for the Upper Blackwater and North Fork Blackwater monitoring stations located on impaired segments.

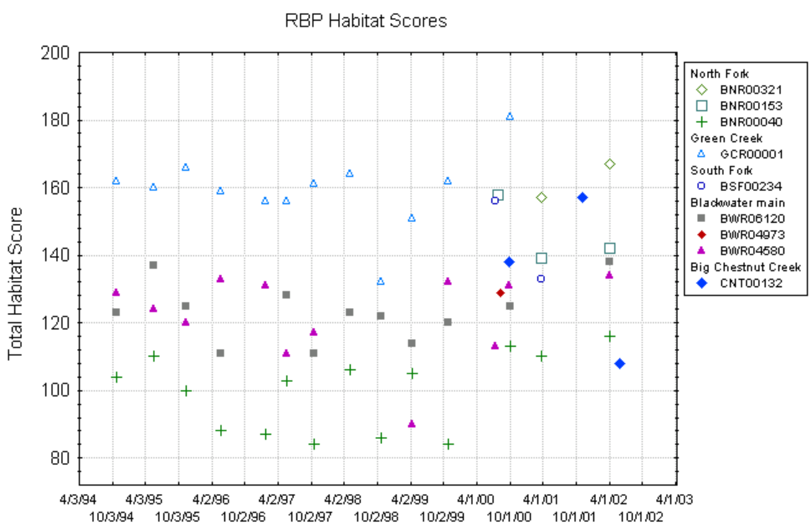


Figure 3.39 RBP total habitat scores

3.5 Toxic Pollutants - Surface Water

Virginia Water Quality Standards list acute and chronic criteria for surface waters (9 VAC 25-260-140). These numeric criteria were developed for metals, pesticides, and other toxic chemicals which can cause acute and chronic toxicity effects on aquatic life and human health. Available water quality data were compared to these criteria to determine possible effects on aquatic life. Ammonia data were collected during special study and monthly ambient monitoring runs (see Section 3.4.2, Figures 3.20 and 3.21). For the period of record at each station, only one exceedance of the chronic criteria was noted at Station BWR045.80 on July 18, 1994. All other recorded data were lower than the respective acute and chronic ammonia levels.

3.6 Toxic Pollutants - Sediment

Virginia Water Quality Standards and updated 305(b) assessment guidance for sediment parameters were consulted to determine if the available data indicate high levels for metals, pesticides, or other constituents that can cause acute or chronic toxicity effects on aquatic life. Sediment data were assessed using EPA Probable Effects Concentration (PEC) thresholds and the NOAA Effects Range-Median (ER-M) and Effects Range-Low (ER-L) screening values. No exceedances were noted for sampled parameters.

3.7 EPA Toxicity Testing

Toxicity tests were conducted by EPA Region 3 to help determine possible toxic effects on benthic organisms in Upper Blackwater River impaired streams (USEPA 2003b). The survival/growth of fathead minnows (*Pimephales promelas*) and the survival/reproduction of *Ceriodaphnia dubia* were measured using ambient water samples collected from three stations in the Upper Blackwater River watershed: BNR000.40, BWR061.20, and BWR045.80. Samples from these sites caused significant mortality to fathead minnows in the bioassay tests. These data indicate potential toxicity problems in Upper Blackwater River streams, possibly due to elevated ammonia levels, or other constituents.

Transport of toxic substances adsorbed to particulate material may be an important mechanism in the movement of toxins from agricultural and urban lands to streams. It is possible that through the implementation of the sediment and phosphorus TMDLs for Upper Blackwater River and North Fork Blackwater River, the potential problem of toxicity will be addressed.

Additional toxicity testing and chemical analyses are required to verify these results and to further investigate possible toxic effects on aquatic organisms. In order to address the potential source(s) of the toxicity in these streams, it is recommended that DEQ complete additional monitoring. This could be accomplished through the initiation of a special study and/or monitoring of fish tissue. As with other pollutants, if toxic chemicals are found to exist at toxic levels in these streams in the future, then TMDLs will be developed for these constituents as well.

3.8 Summary

Water quality and habitat data indicate that excessive sedimentation is a primary cause of the listed benthic community impairments in the Upper Blackwater River and North Fork Blackwater River. Low DO conditions in the North Fork Blackwater River also likely contribute to the listed impairment for this stream. DO levels in the Upper Blackwater River segment were above established water quality criteria, although these data were somewhat depressed. Excessive nutrient inputs are believed to be responsible for the low dissolved oxygen levels measured during the diel DO monitoring study. N:P ratios identify phosphorus as the limiting nutrient that controls algal growth and the corresponding reduction in DO levels during summer, low flow periods. Ammonia levels were also high for the North Fork Blackwater and Blackwater mainstem; however, the ammonia chronic criteria was only exceeded on one occasion at one station. In addition, EPA toxicity test results indicate the need for additional toxic monitoring and follow-up investigation to determine the likelihood of toxic pollutant effects on the benthic community.

As a result of this study, sediment TMDLs were developed for the Upper Blackwater River and North Fork Blackwater River and a phosphorus TMDL was developed for the North Fork Blackwater River. BMP practices employed during implementation of these TMDLs and the previously developed bacteria TMDLs will help alleviate other possible benthic community stressors including ammonia toxicity and other factors.

SECTION 4

SOURCE ASSESSMENT - SEDIMENT AND PHOSPHORUS

Point and nonpoint sources of sediment and phosphorus were assessed in TMDL development. The source assessment was used as the basis of model development and analysis of TMDL allocation options. A variety of information was used to characterize sources in impaired and reference watersheds including: agricultural and land use information, water quality monitoring and point source data, soils data, past TMDL studies, literature sources, and other information. Procedures and assumptions used in estimating sediment and phosphorus sources in the impaired subwatersheds are described in the following sections. Similar procedures were used to derive the required input data for the reference watershed, although the specific data products used varied for each watershed. Whenever possible, data development and source characterization was accomplished using locally-derived information.

4.1 Assessment of Nonpoint Sources

Erosion of the land results in the transport of sediment to receiving waters through various processes. Factors that influence erosion include characteristics of the soil, vegetative cover, topography, and climate. Nonpoint sources, such as agricultural land uses and construction areas, are large contributors of sediment because the percentage of vegetative cover is typically lower. Urban areas can also contribute quantities of sediment to surface waters through the build-up and eventual washoff of soil particles, dust, debris, and other accumulated materials. Pervious urban areas, such as lawns and other green spaces contribute sediment in the same fashion as low-intensity pasture areas or other similar land uses. In addition, streambank erosion and scouring processes can result in the transport of additional sediment loads. Timber operations represent another potential source of sedimentation. Although the sediment yield from undisturbed forests is generally low, clear-cut areas can contribute significant sediment loads.

Phosphorus, because of its tendency to adsorb to soil particles and organic matter, is primarily transported in surface runoff with eroded sediments. Under normal conditions, phosphorus is scarce in the aquatic environment; however, land disturbance activities and fertilizer applications increase phosphorus loading in surface waters. Nonpoint sources of phosphorus include soil erosion, runoff from urban and agricultural lands, animal waste, residential septic systems, and groundwater.

4.1.1 Agricultural Land

Agricultural land was identified as a major source of nutrients and sediment in the impaired watersheds. Agricultural runoff can contribute increased pollutant loads when farm management practices allow soils rich in nutrients from fertilizers or animal waste to be washed into the stream, increasing in-stream sediment and phosphorus levels. The erosion potential of cropland and over-grazed pasture land is particularly high due to the lack of year-round vegetative cover. The use of cover crops and other management practices have been shown to reduce the transport of pollutant loads from agricultural lands.

Land uses in the impaired watersheds are shown in Table 2.1. Watershed land use percentages are also presented in this table.

4.1.2 Livestock

Franklin County ranks as one of the top agriculture producing counties in Virginia, due in large part to livestock sales (NASS 1997). Grazing animals, such as beef and dairy cattle, deposit manure (and nutrients) on the land surface, where it is available for washoff and delivery to receiving waters. Spreading animal manure on agricultural lands also contributes to nutrient washoff. Livestock traffic, especially along stream banks, disturbs the land surface and reduces vegetative cover causing an increase in erosion from these areas.

4.1.3 Forest Land

Agricultural and urban development in these watersheds has replaced some mature forest areas, especially along streams and at lower elevations. The remaining forest lands, generally, occupy higher elevations and agriculturally unproductive areas. The sediment and phosphorus yield from undisturbed forest lands, especially during the growing season, are low due to the amount of dense vegetative cover which stabilizes soils and reduces rainfall impact.

4.1.4 Urban Areas

Urban land uses in the watershed include commercial, industrial, transportation, and residential areas. Urban land uses consist of pervious and impervious areas. Stormwater runoff from impervious areas, such as paved roads and parking lots, contribute pollutants that accumulate on these surfaces directly to receiving waters without being filtered by soil or vegetation. Sediment and phosphorus deposits in impervious areas originate from vehicle exhaust, industrial and commercial activities, outdoor storage piles, wildlife and domestic pet waste, and other sources. According to Novotny and Olem (1994), phosphorus concentrations in urban runoff range from 0.2 to 1.7 mg/L. In addition, stormwater runoff can cause streambank erosion and bottom scouring through high flow volumes, resulting in increased sedimentation and other habitat impacts.

The primary urban sources of sediment and phosphorus are construction sites and other pervious lands. Construction sites have high erosion rates due to the removal of vegetation and top soil. Typical erosion rates for construction sites are 35 to 45 tons per acre per year as compared to 1 to 10 tons per acre per year for cropland. Residential lawns and other green spaces contribute sediment in the same fashion as low-intensity pasture areas or other similar land uses. Fertilizer application on lawns can be a significant source of phosphorus and other pollutants. Wildlife and domestic pet waste is also deposited on pervious urban lands.

Urban land use areas were separated into pervious and impervious fractions based on the estimated percent impervious surface of each urban land use category.

4.1.5 Septic Systems

On-site septic systems have the potential to deliver nutrients to surface waters due to system failure and malfunction. Septic systems treat human waste using a collection system that discharges liquid waste into the soil through a series of distribution lines that comprise the drain field. In properly functioning (normal) systems, phosphates are adsorbed and retained by the soil as the effluent percolates through the soil to the shallow saturated zone. Therefore, normal systems do not contribute phosphorus loads to surface waters. A septic system failure occurs when there is a discharge of waste to the soil surface where it is available for washoff. As a result, failing septic systems can contribute high phosphorus loads to surface waters. Short-circuited systems (those located close to streams) and direct discharges also contribute significant nutrient loads.

Septic system data were needed for the development of a phosphorus TMDL for the North Fork Blackwater River. The population served by each type of septic system (normal, short-circuited, ponded, and direct discharge) was determined using the U.S. Census Data for Year 2000 (Block-Group data) and the assumptions used in the previous fecal coliform TMDL development project (VADEQ 1999). These data were then projected to the current year (2003) using the 2000-2010 annual population growth rate for Franklin County (0.57%) (FCBS 1995).

The number of failing (ponded) septic systems was estimated using a failure rate of 1.3%. The number of short-circuited systems was estimated based on the proximity of unsewered houses to the closest stream. Unsewered houses located within 50 feet (approximately 15 meters) of a perennial stream were assumed to have a short-circuited septic system. These systems are located close enough to surface waters, such that negligible adsorption of phosphorus takes place (Haith et al. 1992).

In some cases, human waste is directly deposited into surface waters from houses without septic systems. These direct discharges are called "straight pipes" and are illegal under Virginia regulations. Houses with straight pipes are typically older structures that are located close to a waterbody. The number of straight pipes was estimated to be equal to 0.5% of the total number of septic systems in the watershed (Baker 1999).

Table 4.1 Septic population in the North Fork Blackwater River watershed (2003 estimates)

Normal	Ponded (Failing)	Short-circuited	Direct discharge
1124	100	16	6

4.1.6 Groundwater

Agriculture and septic systems are two major sources that enrich the groundwater. Phosphorus concentrations in groundwater were based on the results from a nationwide study of mean dissolved nutrients as measured in streamflow (as reported in Haith et al. 1992). The relative percentage of agriculture and forest land in each watershed and septic population data were used to estimate groundwater phosphorus concentrations from the study results

4.2 Assessment of Point Sources

Point sources can contribute sediment and phosphorus loads to surface waters through effluent discharges. These facilities are permitted through the Virginia Pollutant Discharge Elimination System (VPDES) program that is managed by VADEQ. VPDES individual permits are issued to facilities that must comply with permit conditions that include specific discharge limits.

There are three point source discharges located in the Upper Blackwater River watershed that potentially contribute sediment and phosphorus loads to the streams (Table 4.3). There is one VPDES individual permit, Callaway Elementary School (VA0088561), which is located on the South Fork Blackwater River. A permitted TSS concentration of 30 mg/L and a design flow of 0.0019 million gallons/day was used to calculated the sediment contribution from this point source.

General permits are granted for smaller facilities that must comply with a standard set of permit conditions, depending on facility type. Clover Meadow Dairy Farm (VPG120013) and VDOT-Franklin County (VAR101262) are subject to general permit standards. The Clover Meadow Dairy Farm is a confined animal feeding operation (CAFO) general permit which means that it is a no discharge facility. Rather, the loads from the lands governed by this permit have been taken into account by the model and are included in the load allocation. The VDOT-Franklin County facility was issued a stormwater construction permit which includes a limit of 100 mg/L for sediment. The load from this facility was calculated as the average annual modeled runoff in the area times the area governed by the permit (8.73 acres) times the maximum TSS concentration of 100 mg/L. Annual pollutant contributions by each facility are listed in Table 4.

Table 4.2 VPDES point source loads for TSS and total phosphorus

Stream	Facility Name	VPDES Permit No.	Discharge Type	Design Flow (MGD)	Permitted Concentration (mg/L)	TSS Load (metric tons/year)	Phosphorus Load (metric tons/year)
South Fork Blackwater	Callaway Elementary	VA0088561	Municipal	0.0019	30 TSS	0.0789	
North Fork Blackwater	Clover Meadow Dairy Farm	VPG120013	General	N/A	N/A	N/A	N/A
Unnamed Tributary to South Fork Blackwater	VDOT-Franklin County	VAR101262*	General	0.0032	100 TSS	0.447	

*Permitted load for this facility was calculated as the average annual modeled runoff times the area governed by the permit times a maximum TSS concentration of 100 mg/L. Flow was based on the average annual runoff from row crop lands.

SECTION 5

WATERSHED MODELING

5.1 Overall Technical Approach

As discussed in Section 2.1, a reference watershed approach was used in this study to develop TMDLs for the Upper Blackwater River. A watershed model was used to simulate the sediment and phosphorus loads from potential sources in impaired and reference watersheds. The watershed model used in this study was the Generalized Watershed Loading Functions (GWLF) model (Haith and Shoemaker 1987). GWLF modeling was accomplished using the BasinSim 1.0 watershed simulation program, which is a windows-based modeling system that facilitates the development of model input data and provides additional functionality (Dai et al. 2000). Numeric endpoints were based on the loadings that were calculated for the reference watershed. TMDLs were then developed for each impaired stream segment based on these endpoints and the results from load allocation scenarios.

5.2 Watershed Model

TMDLs were developed using BasinSim 1.0 (GWLF model) and the Tetra Tech Stream Module (discussed below). The GWLF model, which was originally developed by Cornell University (Haith and Shoemaker 1987, Haith et al. 1992), provides the ability to simulate runoff, sediment, and nutrient loadings from watersheds given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data. GWLF is a continuous-simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on daily water balance totals that are summed to give monthly values.

GWLF is an aggregate distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple land use/cover scenarios. Each area is assumed to be homogenous with respect to various attributes considered by the model. Additionally, the model does not spatially distribute the source areas, but aggregates the loads from each area into a watershed total. In other words, there is no spatial routing. For subsurface loading, the model acts as a lumped parameter model using a water balance approach. No distinctly separate areas are considered for subsurface flow contributions. Daily water balances are computed for an unsaturated zone as well as for a saturated subsurface zone, where infiltration is computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration.

In order to consider the spatial distribution of sources in the TMDL development, the Upper Blackwater River watershed was divided into 13 subbasins (Figure 5.1). The flow and pollutant loadings from each subwatershed are routed through the stream networks using a stream routing and transport module developed by Tetra Tech. The transport module also has the capability of assessing streambank erosion. GWLF is a continuous-simulation model that uses daily time steps for weather data and water balance calculations. The GWLF simulation results, including flow and sediment load, for each subwatershed are used to drive the stream flow routing, sediment transport, as well as streambank erosion simulation. As the routing and streambank erosion simulation uses hourly or smaller time step, the daily GWLF flow was extrapolated to a triangular hydrograph at an hourly increment by using the TR-55 procedures.

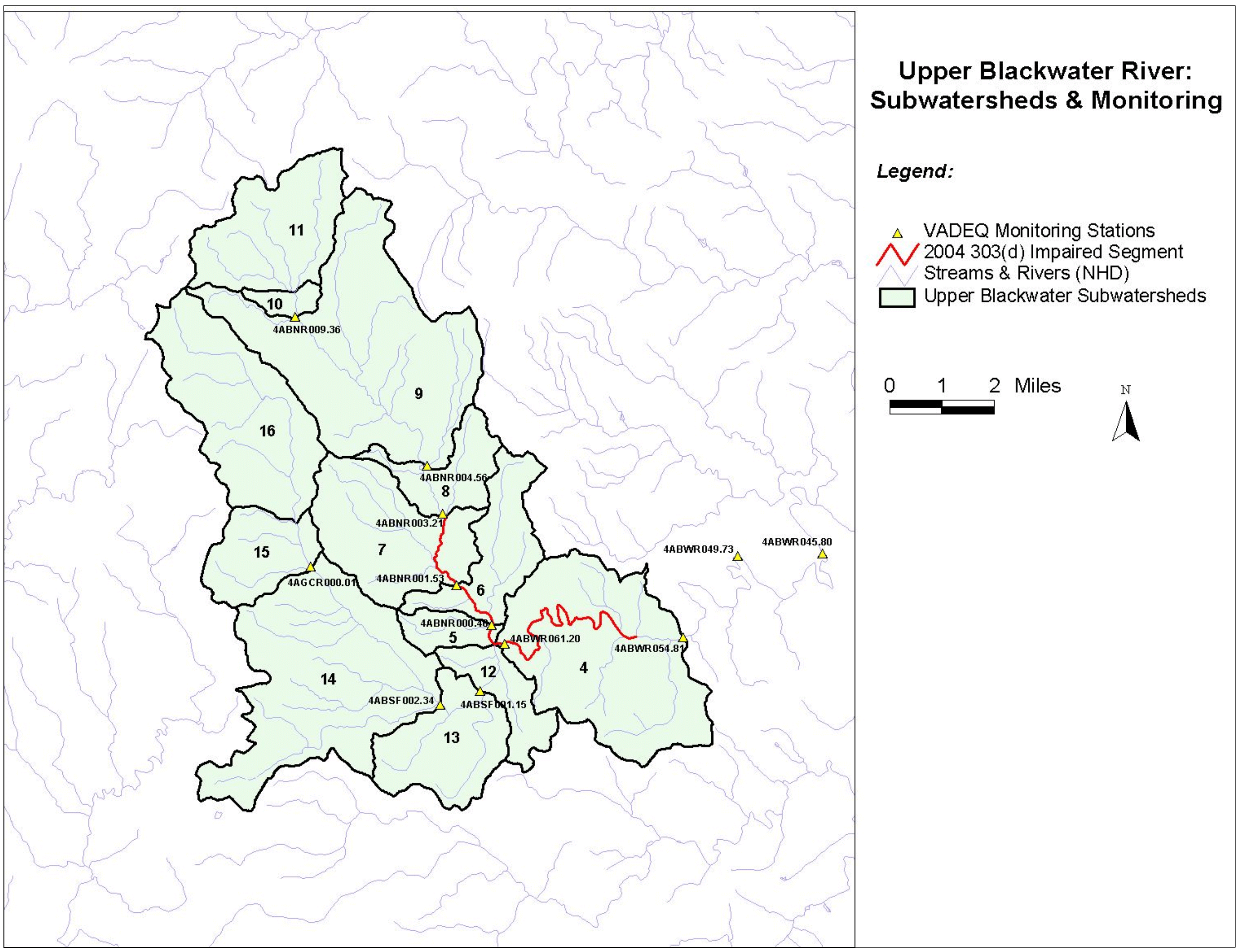


Figure 5.1 Upper Blackwater River subwatersheds

GWLF models surface runoff using the Soil Conservation Service Curve Number (SCS-CN) approach with daily weather (temperature and precipitation) inputs. Erosion and sediment yield are estimated using monthly erosion calculations based on the Universal Soil Loss Equation (USLE) algorithm (with monthly rainfall-runoff coefficients) and a monthly composite of KLSCP values for each source area (e.g., land cover/soil type combination). The KLSCP factors are variables used in the calculations to depict changes in soil loss/erosion (K), the length/slope factor (LS), the vegetation cover factor (C), and the conservation practices factor (P). A sediment delivery ratio based on watershed size and a transport capacity based on average daily runoff is applied to the calculated erosion to determine sediment yield for each source area. Point source discharges also can contribute to loads to the stream. Evapotranspiration is determined using daily weather data and a cover factor dependent on land use/cover type. Finally, a water balance is performed daily using supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage, and evapotranspiration values. All of the equations used by the model can be found in the original GWLF paper (Haith and Shoemaker 1987) and GWLF User's Manual (Haith et al. 1992).

For execution, the model requires three separate input files containing transport, nutrient, and weather-related data. The transport file (TRANSPRT.DAT) defines the necessary parameters for each source area to be considered (e.g., area size, curve number) as well as global parameters (e.g., initial storage, sediment delivery ratio) that apply to all source areas. The nutrient file (NUTRIENT.DAT) specifies the various loading parameters for the different source areas identified (e.g., number of septic systems, urban source area accumulation rates, manure concentrations). The nutrient file is necessary for the model to run but is not used in any of the calculations. The weather file (WEATHER.DAT) contains daily average temperature and total precipitation values for each year simulated.

Streambank Erosion Simulation Module

The streambank erosion simulation module employed the algorithm used in the Annualized Agricultural Nonpoint Source (AnnAGNPS) model (Theurer and Bingner, 2000). Sediment transport/routing and streambank erosion simulation were performed using three particle size classes (clay, silt, and sand), and the simulation time-step is one hour. For each subwatershed channel segment, the incoming sediment or pollutant load is the total of local sources plus the loading from upstream subwatersheds. If the incoming sediment was greater than the sediment transport capacity specific to the physical features and the magnitude of flow of that segment, then the sediment deposition algorithm was used. If the incoming sediment is less than or equal to the sediment transport capacity, the sediment discharge at the outlet of the segment will be calculated as a function of the sediment transport capacity as well as the sediment availability factor for an erodible channel. Since the sediment transport capacity is specific to the magnitude of flow, the capacity for each particle size was calculated for each increment of the streamflow hydrograph. The erodibility of a channel was reflected by the sediment availability factor for the three particle sizes. These factors were assigned based on site-specific information regarding bank stability and vegetation cover conditions, and were further calibrated where monitoring data were available.

5.3 Model Setup

Watershed data needed to run the GWLF model in BasinSim 1.0 were generated using GIS spatial coverages, water quality monitoring and streamflow data, local weather data, literature values, and other information. Subwatershed boundaries for the Upper Blackwater River were delineated based on hydrologic and topographic data (USGS 7.5 minute digital topographic maps (24K DRG - Digital Raster Graphics), and the location of DEQ monitoring stations. Reference watersheds were also delineated using these data. The outlet of the Upper Blackwater River watershed is the downstream limit of the impaired segment of the mainstem. The reference watershed outlet is located at the VADEQ biomonitoring station on Big Chestnut Creek. To equate target and reference watershed areas for TMDL development, the total area for the reference watershed was reduced to be equal to the area of each Blackwater subwatershed, after hydrology calibration. To accomplish this, land use areas (in the reference watershed) were proportionally reduced based on the percent land use distribution.

Local rainfall and temperature data were used to simulate flow conditions in modeled watersheds. Daily precipitation and temperature data were obtained from local National Climatic Data Center (NCDC) weather stations. Weather stations that correspond with the modeled watersheds are shown in Table 5.1. The period of record selected for model calibration runs (January 1, 1991 through September 30, 1998 for the Big Chestnut Creek and Blackwater River watershed models) was based on the availability of recent weather data and corresponding streamflow records. Although the USGS flow data ends on 9/30/2002, it was observed that the data starting from August 1998 was much lower than normal flow. Therefore, the data recorded after September 1998 was not used in calibration. The weather data collected at the NCDC station of Rocky Mount (precipitation and temperature data) were used to construct the weather file used for both watershed simulations.

Table 5.1 Weather stations used in GWLF models

Watershed	Weather Station	Data Type	Data Period
Upper Blackwater River	Rocky Mount	Daily Precipitation, Daily Temperature	4/1/1990 - 12/31/2002

Daily streamflow data are needed to calibrate watershed hydrologic parameters in the GWLF model. The USGS gage 02056900, located on the Blackwater River near Rocky Mount, Virginia, was used to calibrate both the reference and impaired watersheds. Table 5.2 lists the USGS gaging stations along with their period of record for the appropriate watersheds.

Table 5.2 USGS gaging stations used in modeling studies

Modeled Watershed	USGS station number	USGS gage location	Data Period
Blackwater River	02056900	Rocky Mount, VA	1/1/1991 to 9/30/1998
Big Chestnut Creek	02056900	Rocky Mount, VA	1/1/1991 to 9/30/1998

5.4 Explanation of Important Model Parameters

In the GWLF model, the nonpoint source load calculation is affected by terrain conditions, such as the amount of agricultural land, land slope, soil erodibility, farming practices used in the area, and by background concentrations of nutrients (nitrogen and phosphorus) in soil and groundwater. Various parameters are included in the model to account for these conditions and practices. Some of the more important parameters are summarized as follows:

Areal extent of different land use/cover categories: VADCR and MRLC land use coverages were used to calculate the area of each land use category in impaired and reference watersheds, respectively.

Curve number: This parameter determines the amount of precipitation that infiltrates into the ground or enters surface water as runoff. It is based on specified combinations of land use/cover and hydrologic soil type and is calculated directly using digital land use and soils coverages. Soils data were obtained from the Holston River SWCD and NRCS. This information is presented in the Washington County soil survey. The State Soil Geographic (STATSGO) database for Virginia, developed by NRCS, was the source of soils data for the Walker Creek watershed.

K factor: This factor relates to inherent soil erodibility, and it affects the amount of soil erosion taking place on a given unit of land. The K factor and other Universal Soils Loss Equation (USLE) parameters were downloaded from the NRCS Natural Resources Inventory (NRI) database (1992). Average values for specific crops/land uses in Franklin County were used. The predominant crop grown in these watersheds is corn; therefore, cropland values were based on data collected in corn crops.

LS factor: This factor signifies the steepness and length of slopes in an area and directly affects the amount of soil erosion.

C factor: This factor is related to the amount of vegetative cover in an area. In agricultural areas, this factor is largely controlled by the crops grown and the cultivation practices used. Values range from 0 to 1.0, with larger values indicating a lower potential for erosion.

P factor: This factor is directly related to the conservation practices used in agricultural areas. Values range from 0 to 1.0, with larger values indicating a higher potential for erosion.

Sediment delivery ratio: This parameter specifies the percentage of eroded sediment delivered to surface water and is empirically based on watershed size.

Unsaturated available water-holding capacity: This parameter relates to the amount of water that can be stored in the soil and affects runoff and infiltration.

Other less important factors that can affect sediment loads in a watershed also are included in the model. More detailed information about these parameters and those outlined above can be obtained from the GWLF User's Manual (Haith et al. 1992). Pages 15 through 41 of the manual provide specific details that describe equations and typical parameter values used in the model.

5.5 Hydrology Calibration

Using the input files created in the BasinSim 1.0, GWLF predicted overall water balances in impaired and reference watersheds. As discussed in Section 5.3, the modeling period is determined based on the availability of weather and flow data that were collected during the same time period. For both watersheds (Upper Blackwater River and Big Chestnut Creek) weather data obtained from the NCDC meteorological station located at Rocky Mount were used to model the watersheds. However, the calibration period was governed by the availability of the USGS gaging data. Both the Upper Blackwater River watershed and the Big Chestnut Creek watershed (reference watershed) were calibrated for a period of over seven years from 1/1991 to 9/1998 using the streamflow gage data from the nearby USGS gage 02056900 on the Blackwater River near Rocky Mount. Although flow data at this gage were available up until 9/30/2002, the weather and flow data did not appear to match beginning in 1998. It was observed that the data starting from September 1998 was much lower than normal flow. Therefore, the data recorded after September 1998 was not used in hydrology calibration. Although the streamflow gage is in close proximity to the reference and the impaired streams, the gage did not coincide with the pour point of the watersheds. Hence, the streamflow measurements were normalized by area to facilitate calibration. Calibration statistics are presented in Table 5.3. These results indicate a good correlation between simulated and observed results for these watersheds. A total flow volume error percentage of less than six percent was achieved in calibration of the model for the Big Chestnut Creek watershed and less than two percent for the Upper Blackwater watershed. In general the seasonal trends and peaks are captured reasonably well for the seven year period in the reference and impaired watersheds. Hydrology calibration results and the modeled time period for the reference and the impaired watersheds are given in Figures 5.2 and 5.3. Differences between observed and modeled flows in these watersheds are likely due to inherent errors in flow estimation procedures based on normalization for watershed size and possibly due to the proximity of the location of the weather station to the watersheds and the flow gage.

Table 5.3 GWLF flow calibration statistics

Modeled Watershed	Simulation Period	R^2 (Correlation) Value	Total Volume % Error
Big Chestnut Creek	1/1/91 - 9/30/98	0.5625	5.3%
Upper Blackwater River	1/1/91 - 9/30/98	0.5651	1.7%

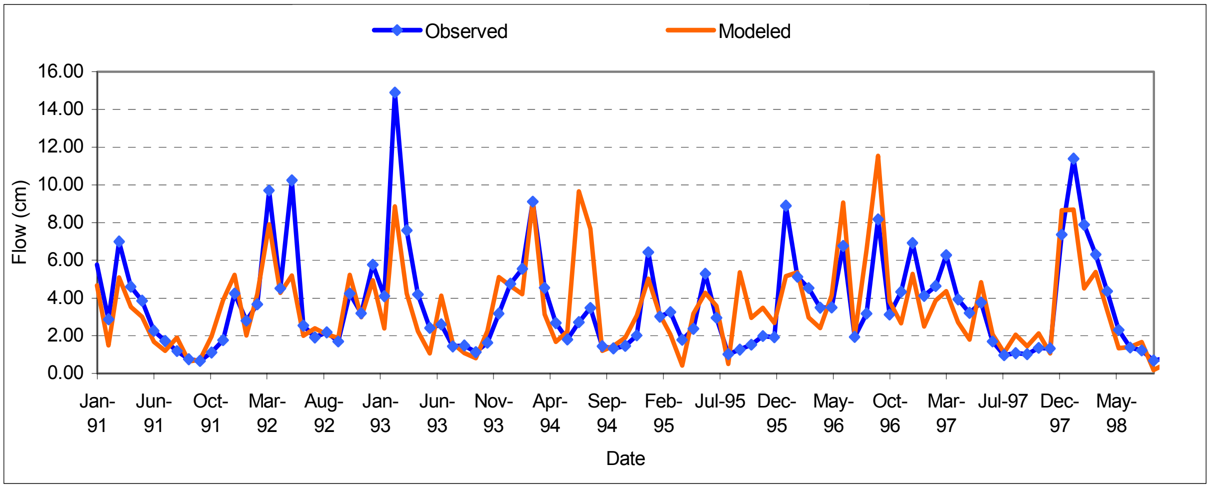


Figure 5.2 Hydrology calibration - Big Chestnut Creek at modeled watershed outlet (USGS 02056900, 1/1/91 - 9/30/98)

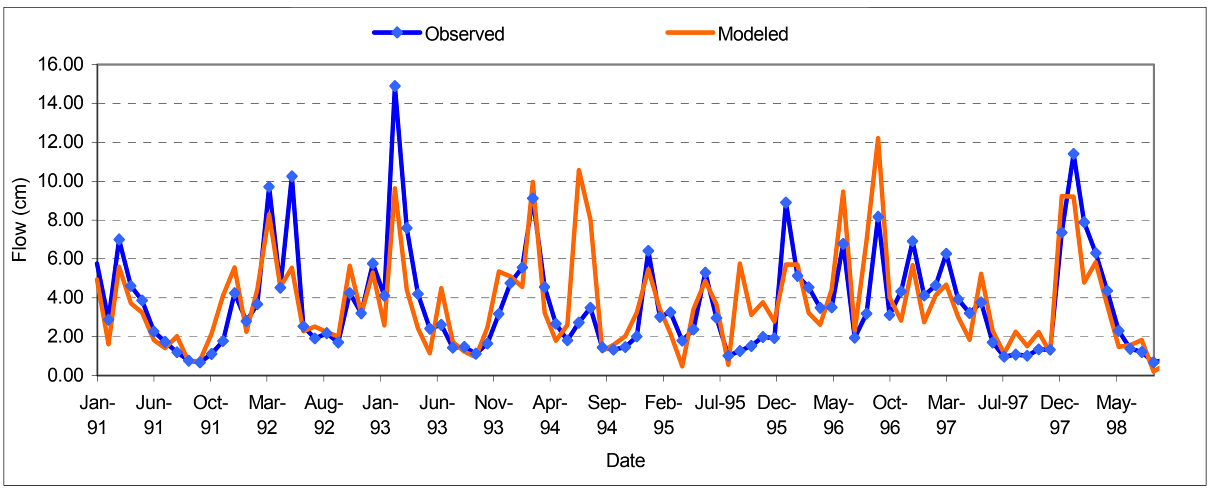


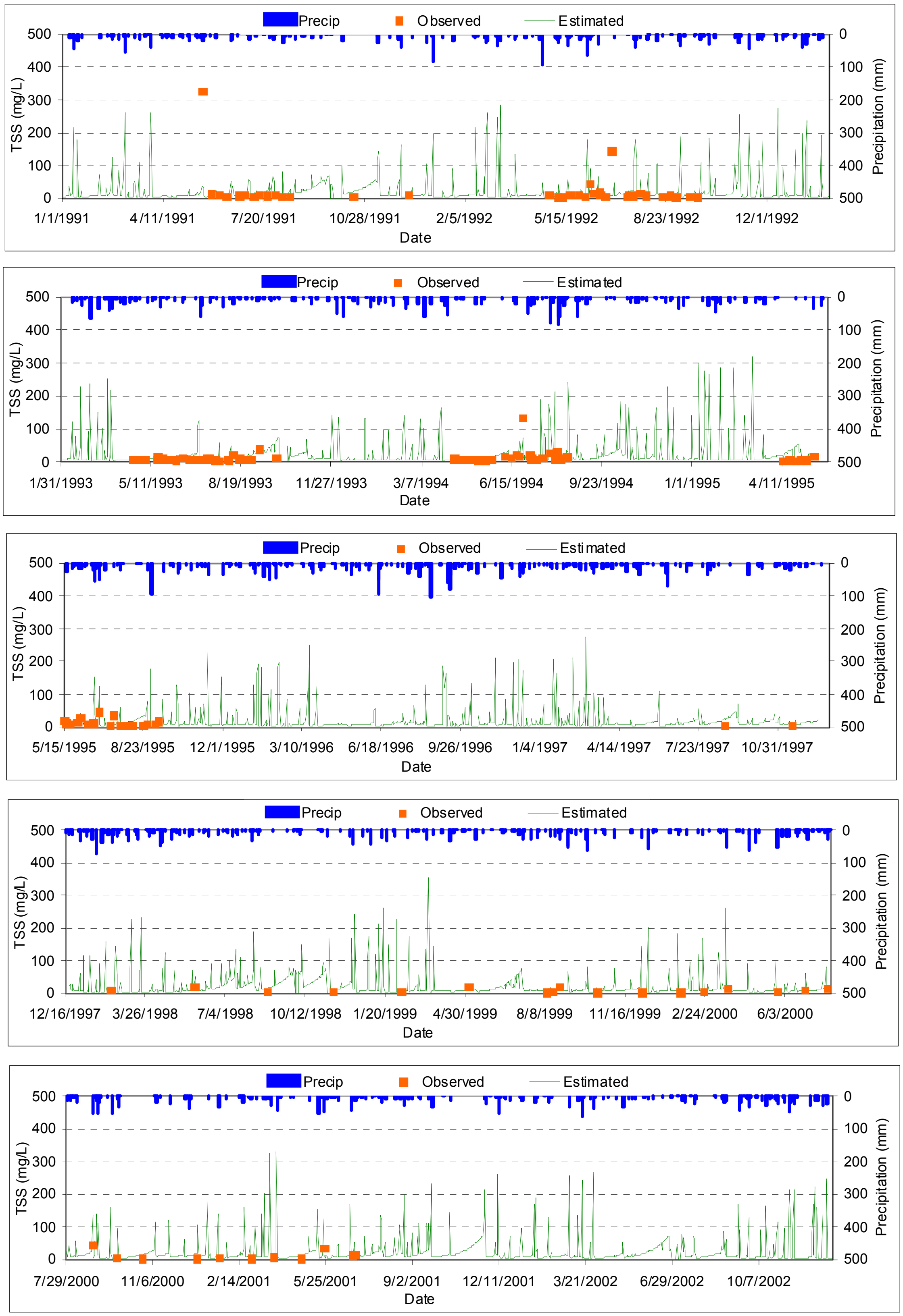
Figure 5.3 Hydrology calibration - Upper Blackwater River at modeled watershed outlet (USGS 02056900, 1/1/91 - 9/30/98)

5.6 Water Quality Calibration

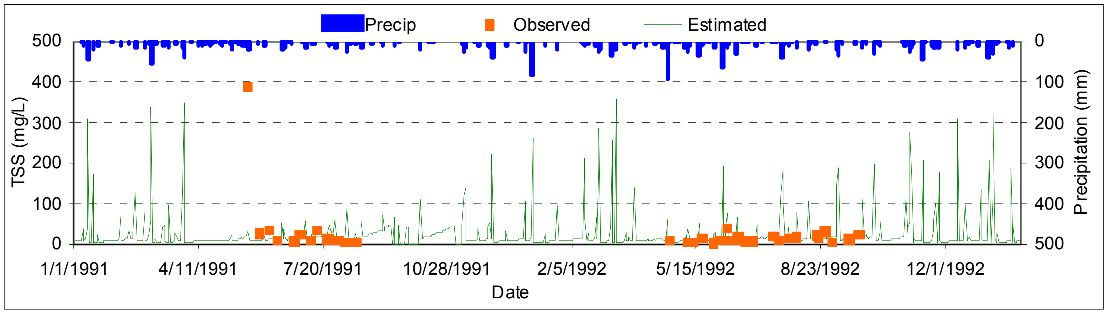
Using the input files created in the BasinSim 1.0, GWLF predicted concentrations of total suspended solids (TSS) and total phosphorus (TP) in impaired and reference watersheds. The time period used for water quality calibration and verification for both the Upper Blackwater River watershed and the Big Chestnut Creek watershed (reference watershed) was from 1/1/1991 to 12/31/2002. Figures 5.4 through 5.18 show the comparison of observed and modeled TSS concentrations and precipitation at various monitoring stations in the Upper Blackwater River watershed. The comparison of observed and modeled TP concentrations and precipitation are shown in Figures 5.19 through 5.33.

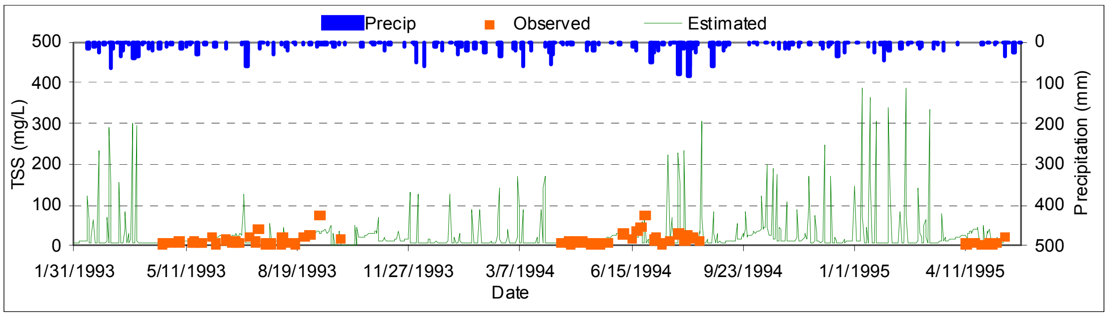
The modeled concentrations compare well with the observed data. The magnitude and trend of the modeled results generally agree with the observed values.

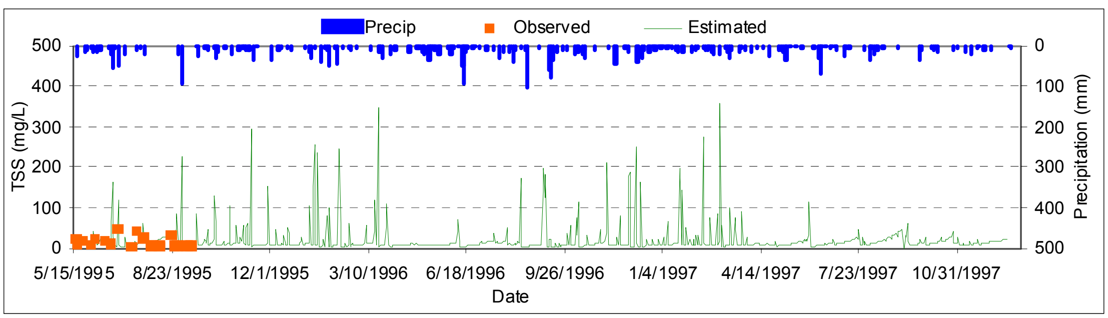
Figures 5.4 - 5.8 Comparison of observed and modeled TSS concentrations at monitoring station 4ABWR045.80

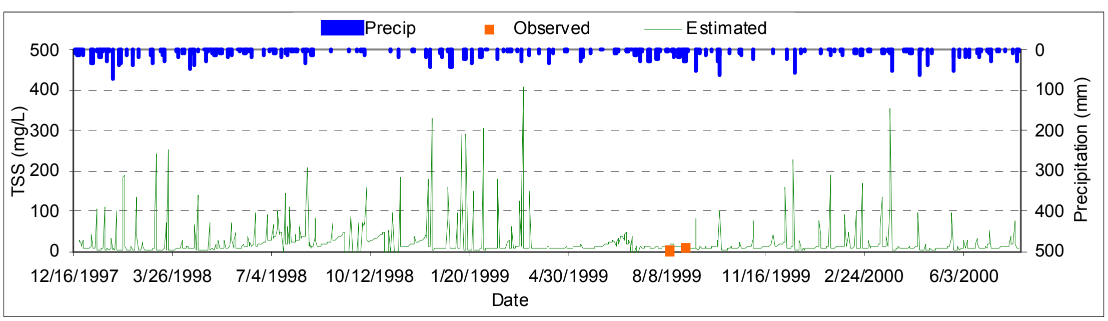


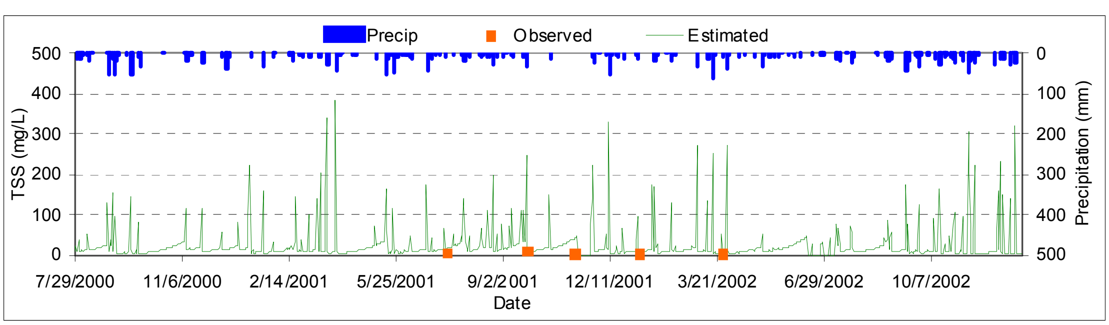
Figures 5.9 - 5.13 Comparison of observed and modeled TSS concentrations at monitoring station 4ABWR061.20



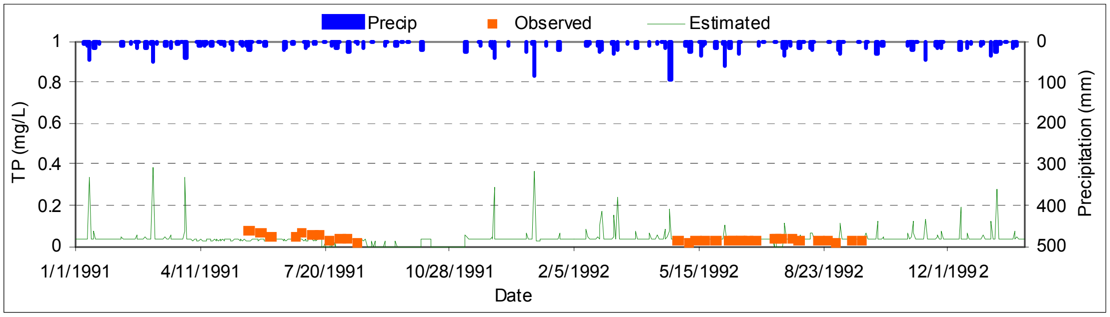


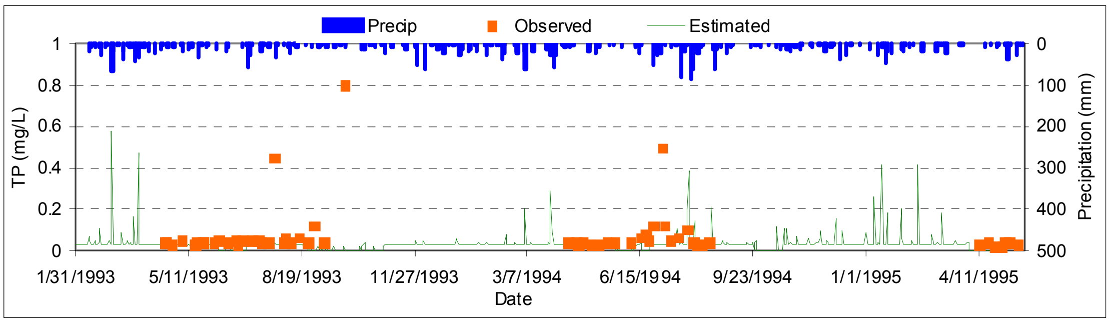


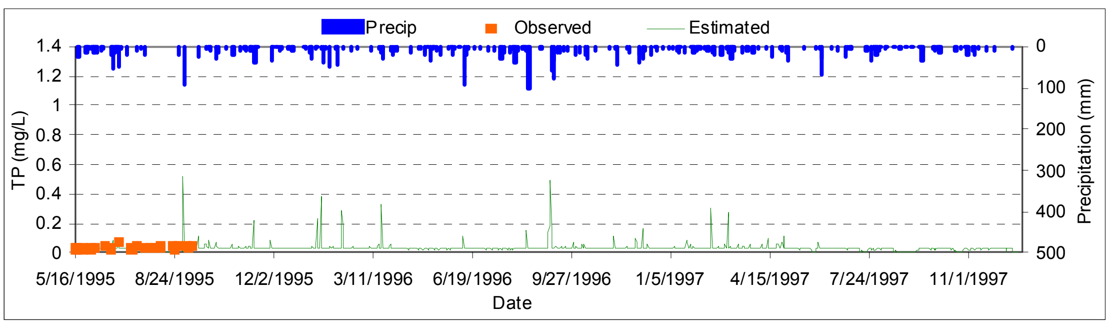


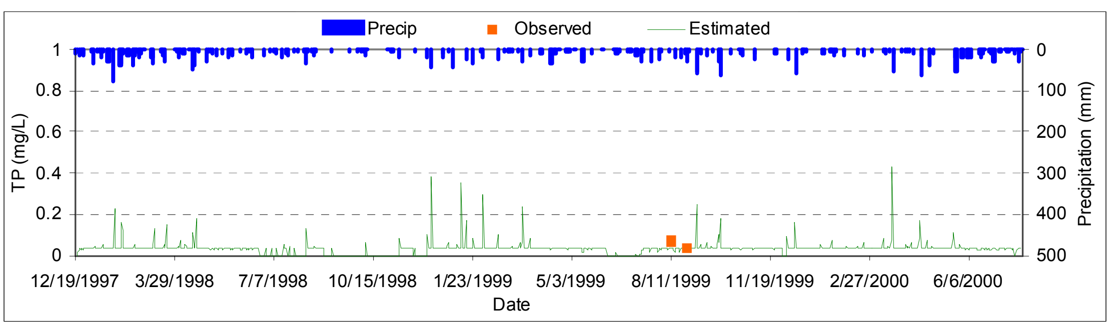


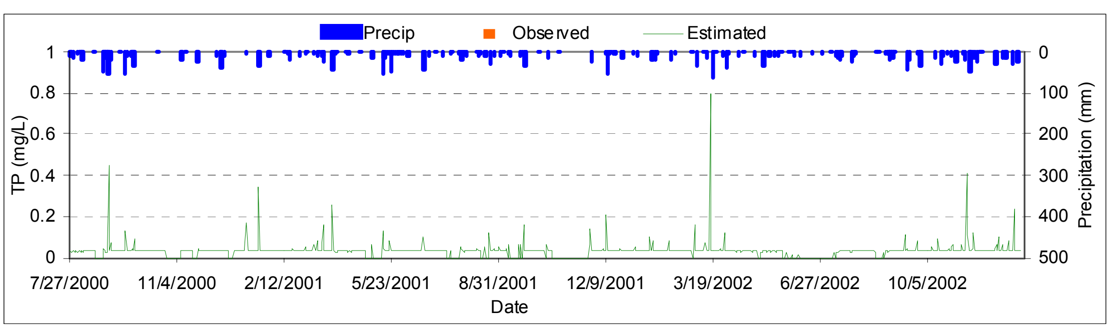
Figures 5.14 - 5.18 Comparison of observed and modeled TSS concentrations at monitoring station 4ABNR000.40



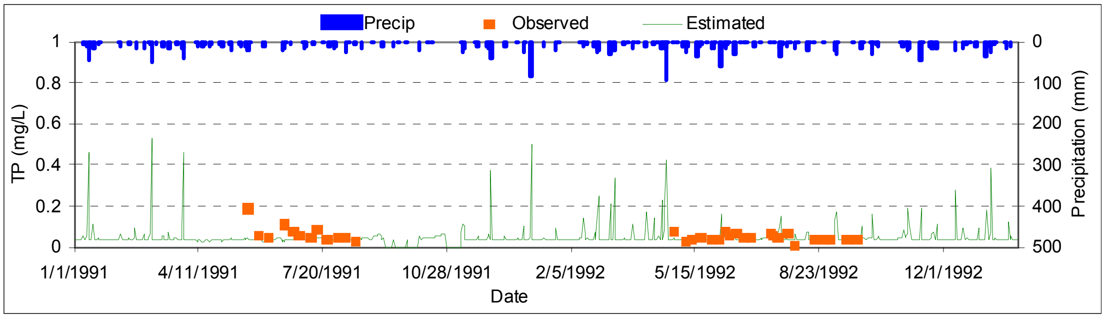


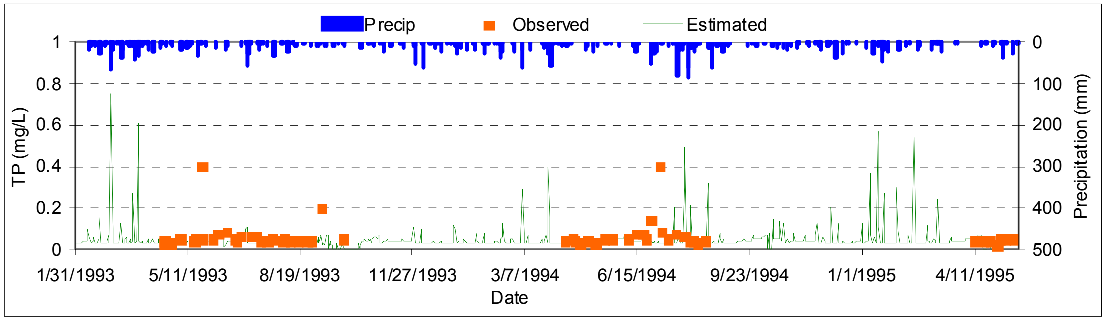


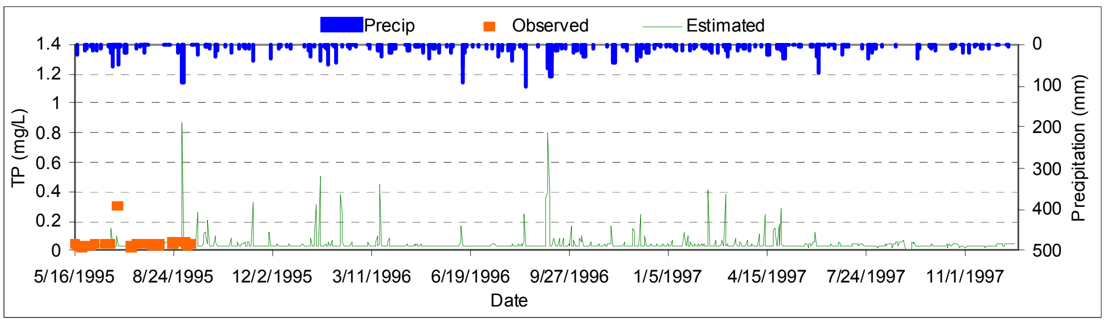


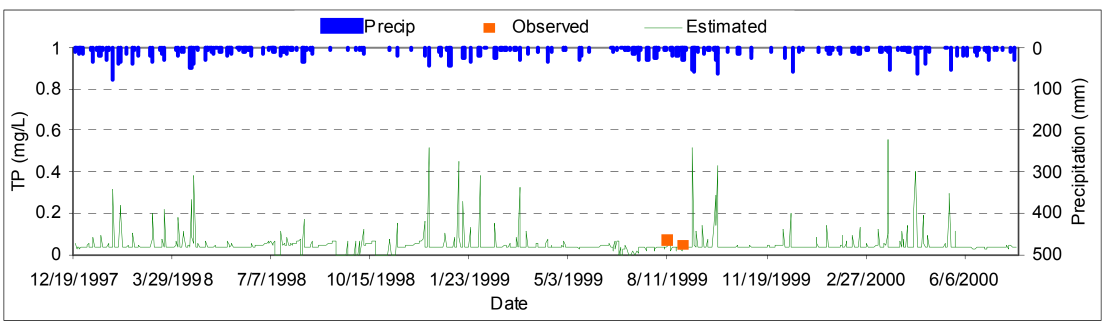


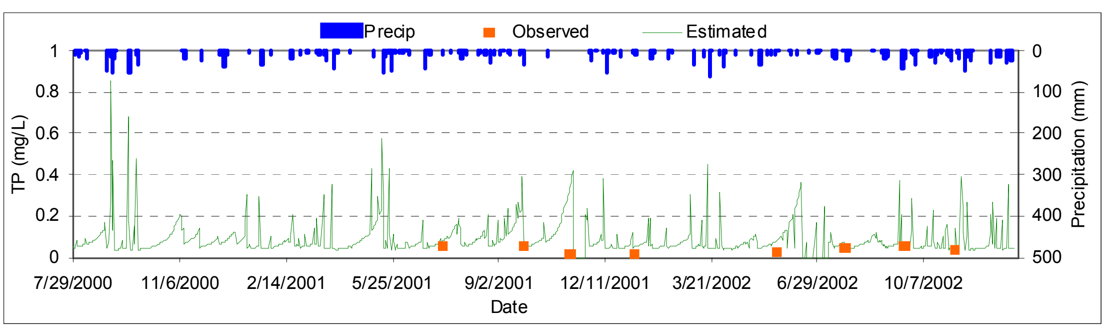
Figures 5.19 - 5.23 Comparison of observed and modeled TP concentrations at monitoring station 4ABNR009.36



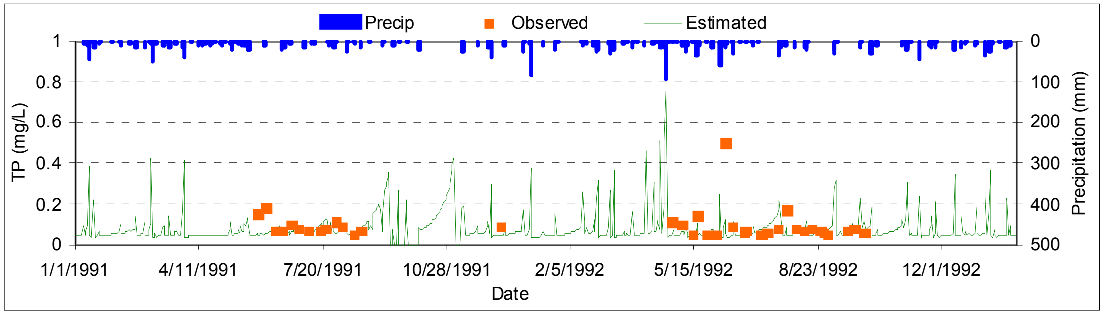


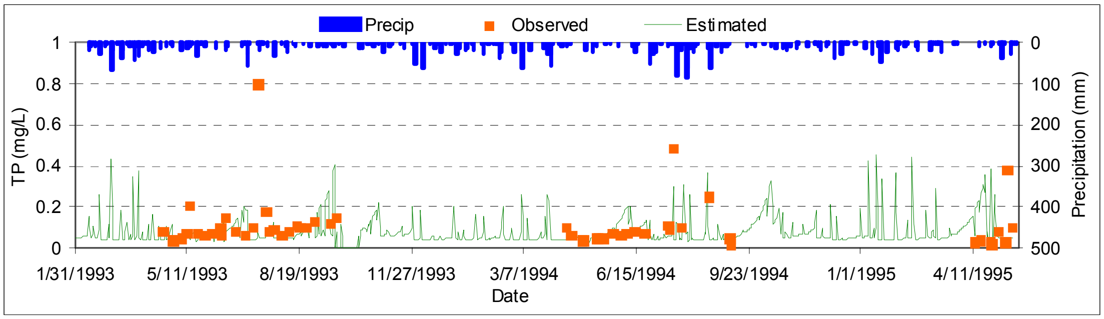


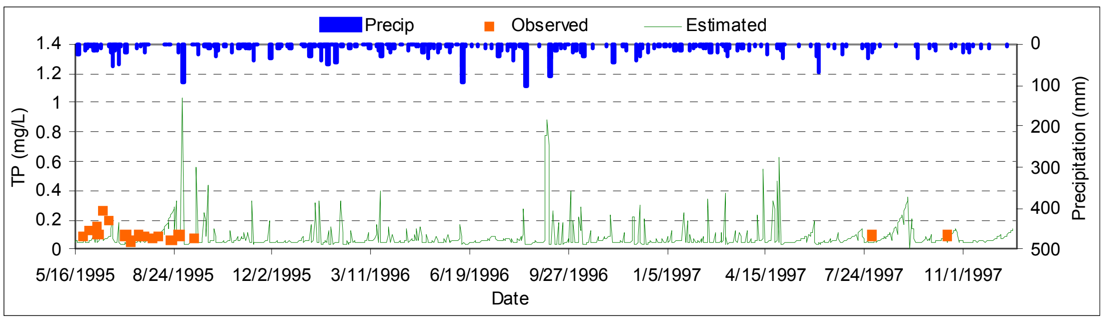


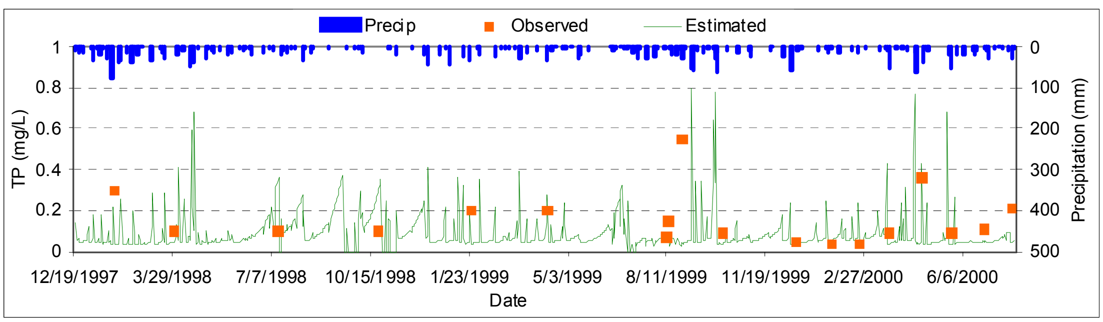


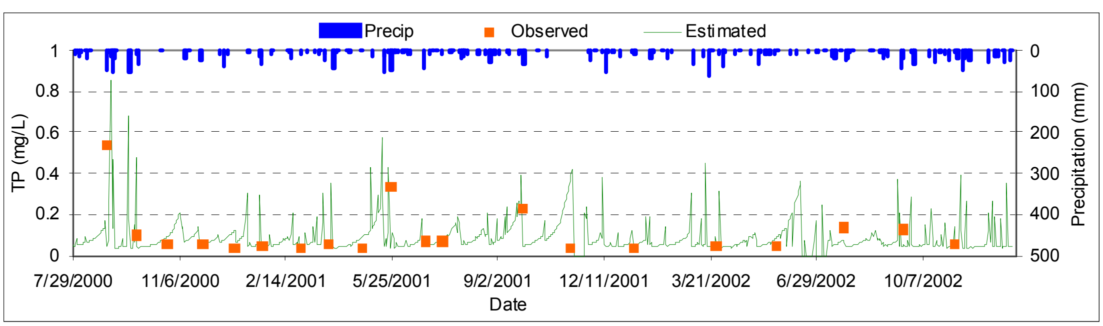
Figures 5.24 - 5.28 Comparison of observed and modeled TP concentrations at monitoring station 4ABNR004.56











Figures 5.29 - 5.33 Comparison of observed and modeled TP concentrations at monitoring station 4ABNR000.40

Figures 5.34 and 5.35 show the statistical comparisons of the observed and modeled TSS and TP data at the monitoring stations where data were available. The estimated values appear close to the observed values. The maximum values for the observed data appear to be slightly higher than the estimated values. This is due to the fact that the estimated values are calculated as a daily average, whereas the observed values are instantaneous records.

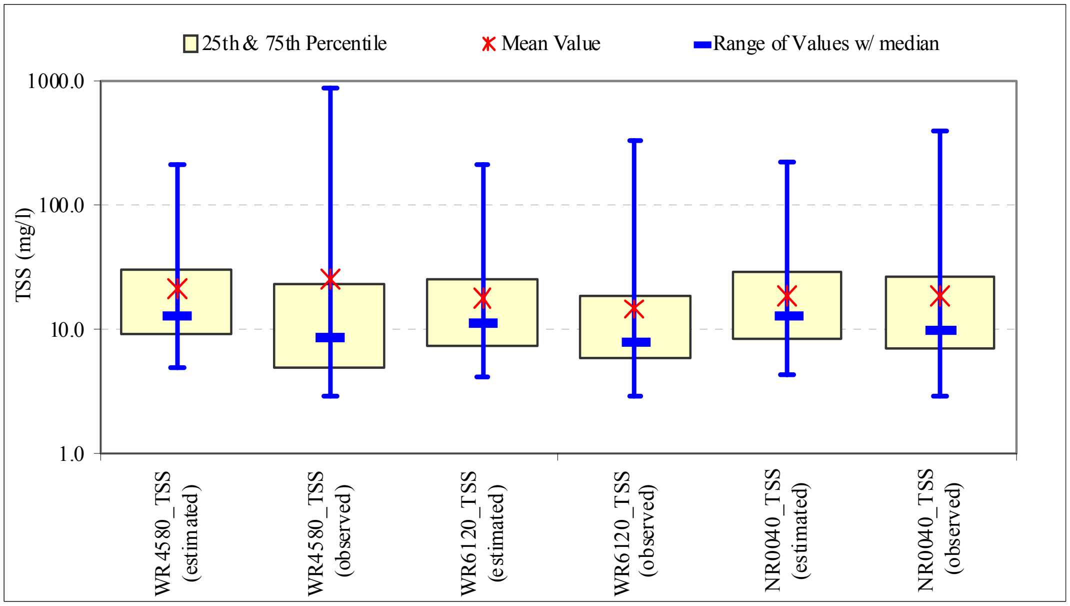


Figure 5.34 Statistical comparison of observed and modeled TSS concentrations at three monitoring stations

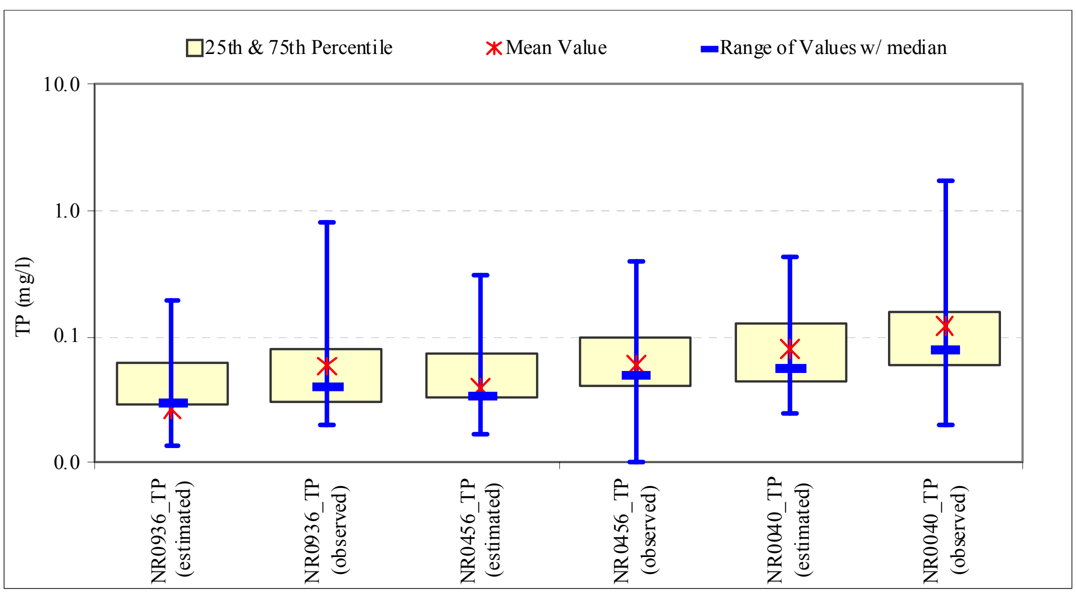


Figure 5.35 Statistical comparison of observed and modeled TP concentrations at three monitoring stations

SECTION 6

TMDL METHODOLOGY

6.1 TMDL Calculation

Impaired and reference watershed models were calibrated for hydrology using the same modeling periods and weather input files. To establish baseline (reference) loadings for sediment the GWLF model results for Big Chestnut Creek were used. For TMDL calculation both the calibrated reference and impaired watersheds were modeled for a 12 and a half year period from 4/1/1990 to 12/31/2002. This was done to standardize the modeling period. Based on the weather and limited flow data it is assumed that this period sufficiently captures hydrologic and weather conditions. In addition, the total area for the reference watershed was reduced to be equal to each target subwatershed, as discussed in Section 5.3. This was necessary because watershed size influences sediment delivery to the stream and other model variables.

The 12-year means for pollutants of concern were determined for each land use/source category in the reference and the impaired watershed. The first nine months of each model run were excluded from the pollutant load summaries because the GWLF model takes a few months in the first year to stabilize. Model output is only presented for the years following the initialization months (1/1/1991 to 12/31/2002), although the model was run for a twelve and a half year time period.

The existing and allocated average annual sediment loads and percent reductions for the entire Upper Blackwater River watershed are presented in Table 6.1. Table 6.2 shows the overall loads and percent reductions for those subbasins within the North Fork Blackwater River watershed. The loads in both tables are sums of the loads from each subbasin by source within that watershed; the total is a sum of loads from all sources. More detailed allocation tables with the loads and percent reductions for each individual subbasin are presented in Appendix A.

The sediment loads contributed by point sources in the Upper Blackwater River watershed were added to the most adjacent stream segments and routed downstream on a daily basis. Point source loads are presented in the tables as a source category. The sediment load contributed by the VDOT facility (general stormwater permit #VAR101262) was calculated based on the area governed by the permit. This load was subtracted from the load allocation calculated for the “Pasture/Hay” source category, so as not to double-count the sediment contribution from this facility.

Table 6.1 Recommended sediment allocations for Upper Blackwater River

Source Category	*Existing Loads*		*Allocated Loads (TMDL minus 10 % MOS)*		
	Sediment Load (ton/yr) *	**Sediment % of Total**	**Sediment Load Allocation (ton/yr) ***	**Sediment % of Total**	**Sediment % Reduction**
Row Crop	6,530.1	57.1%	2,347.9	47.1%	64.0%
Pasture/Hay	4,245.6	37.1%	2,010.1	40.3%	52.7%
Pasture/Hay (stream access)	70.0	0.6%	43.5	0.9%	37.8%
DeciduousForest	579.9	5.1%	579.9	11.6%	0.0%
MixedForest	2.8	0.0%	2.8	0.1%	0.0%
Urban	0.0	0.0%	0.0	0.0%	0.0%
Groundwater	0.0	0.0%	0.0	0.0%	0.0%
PointSource	0.526	0.0%	0.526	0.0%	0.0%
Total	**11,428.8**		**4,984.7**		**56.4%**

* Overall loads for sources were calculated by summing the loads from each source in each subbasin.

Table 6.2 Recommended sediment allocations for North Fork Blackwater River

Source Category	*Existing Loads*		*Allocated Loads (TMDL minus 10 % MOS)*		
	Sediment Load (ton/yr) *	**Sediment % of Total**	**Sediment Load Allocation (ton/yr) ***	**Sediment % of Total**	**Sediment % Reduction**
Row Crop	2,117.5	45.9%	746.3	33.2%	64.8%
Pasture/Hay	2,159.4	46.8%	1,183.3	52.6%	45.2%
Pasture/Hay (stream access)	52.5	1.1%	35.9	1.6%	31.6%
DeciduousForest	280.6	6.1%	280.6	12.5%	0.0%
MixedForest	1.4	0.0%	1.4	0.1%	0.0%
Urban	0.0	0.0%	0.0	0.0%	0.0%
Groundwater	0.0	0.0%	0.0	0.0%	0.0%
PointSource	0.0	0.0%	0.0	0.0%	0.0%
Total	**4,611.5**		**2,247.5**		**51.3%**

* Overall loads for sources were calculated by summing the loads from each source in each subbasin.

The sediment loads contributed by urban areas were minimal in comparison to loads from other sources. The output from the model shows no sediment loadings from urban sources because the loads were so minute that numeric values were truncated within the model resulting in loads of zero tons per year. Although loads are actually being contributed by urban lands, due to the insignificance in size of the loads and the limitation of the model to represent such small loads, the table shows no loads from urban areas.

Although loads for bank erosion and channel deposition are not shown in the tables, the overall allocated loads do account for such stream processes. Allocations to each subbasin for each stream segment (channel) were done while taking into account the amount of sediment gained or lost in each stream channel due to erosion or deposition. When deposition occurs, sediment is subtracted from the load that is carried to downstream channels; when erosion occurs, the sediment load to downstream channels is increased. The actual net erosion/deposition in each channel is shown in the detailed allocation tables in Appendix A.

Table 6.3 shows the existing and allocated average annual total phosphorus loads and percent reductions in the North Fork Blackwater River watershed. As with the sediment loads, total phosphorus loads contributed by point sources in the North Fork Blackwater River watershed were added to the most adjacent stream segments and routed downstream on a daily basis. In addition to point source loads, septic systems are also presented in the table as a source category for total phosphorus loads. More detailed allocation tables with the loads and percent reductions for each individual subbasin are presented in Appendix B.

Table 6.3 Recommended total phosphorus allocations for North Fork Blackwater River

Source Category	*Existing Loads*		*Allocated Loads (TMDL minus 10 % MOS)*		
	TP Load (ton/yr) *	**TP % of Total**	**TP Load Allocation (ton/yr) ***	**TP % of Total**	**TP % Reduction**
Row Crop	1.824	36%	0.702	22%	61%
Pasture/Hay	2.116	42%	1.368	44%	35%
Pasture/Hay (stream access)	0.112	2%	0.080	3%	28%
DeciduousForest	0.199	4%	0.199	6%	0%
MixedForest	0.001	0%	0.001	0%	0%
Urban	0.079	2%	0.070	2%	12%
Groundwater	0.638	13%	0.638	20%	0%
PointSource	0.000	0%	0.000	0%	0%
Septic System	0.097	2%	0.073	2%	24%
Total	**5.066**		**3.132**		**38.2%**

* Overall loads for sources were calculated by summing the loads from each source in each subbasin.

The TMDLs established for the Upper Blackwater River consist of a point source wasteload allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS). The sediment TMDLs for Upper Blackwater River were based on the total load calculated for the Big Chestnut Creek watershed (area adjusted to the appropriate watershed size).

The TMDL equation is as follows:

TMDL = WLA + LA + MOS

The WLA portion of this equation is the total loading assigned to point sources. The LA portion represents the loading assigned to nonpoint sources. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis. An explicit MOS of ten percent was used in TMDL calculations to provide an additional level of protection for designated uses.

TMDLs for Blackwater River and North Fork Blackwater River were calculated by adding reference watershed loads for each pollutant of concern together with point source loads to give the TMDL values. Table 6.4 shows the sediment TMDL for the entire Upper Blackwater River watershed and Table 6.5 shows the sediment TMDL for the North Fork Blackwater River watershed. Table 6.6 shows the total phosphorus TMDL for the North Fork Blackwater River watershed. Note that the WLA values presented in the following tables represent the sum of all point source WLAs in each watershed.

Table 6.4 Sediment TMDL for Upper Blackwater River

Stream	Pollutant	TMDL (tons/yr)	LA (tons/yr)	WLA (tons/yr)	MOS (10%) (tons/yr)	Overall % Reduction
Upper Blackwater River	Sediment	5538.6	4984.2	0.526 *(Callaway Elementary School = 0.0789; VDOT = 0.447)*	553.9	56.4%

Table 6.5 Sediment TMDL for North Fork Blackwater River

Stream	Pollutant	TMDL (tons/yr)	LA (tons/yr)	WLA (tons/yr)	MOS (10%) (tons/yr)	Overall % Reduction
North Fork Blackwater River	Sediment	2497.3	2247.5	0.00	249.7	51.3%

Table 6.6 Total phosphorus TMDL for North Fork Blackwater River

Stream	Pollutant	TMDL (tons/yr)	LA (tons/yr)	WLA (tons/yr)	MOS (10%) (tons/yr)	Overall % Reduction
North Fork Blackwater River	Total Phosphorus	3.480	3.132	0.00	0.348	38.2%

6.2 Waste Load Allocation

Waste load allocations were assigned to each point source facility in the watersheds. Point sources were represented by their current permit conditions and no reductions were required from point sources in the TMDL. Current permit requirements are expected to result in attainment of the WLAs as required by the TMDL. Point source contributions, even in terms of maximum flow, are minimal. Therefore, no reasonable potential exists for these facilities to have a negative impact on water quality and there is no reason to modify the existing permits. The WLA values presented in Tables 6.4, 6.5, and 6.6, represent the sum of all point source WLAs in the watershed. Note that the sediment load contributed by the VDOT facility (general stormwater permit #VAR101262) was calculated based on the area governed by the permit. This load was subtracted from the load allocation calculated for the “Pasture/Hay” source category, so as not to double-count the sediment contribution from this facility.

6.3 Load Allocation

Load allocations were assigned to each source category in the watersheds. The recommended scenarios for Blackwater River (Tables 6.1 through 6.3) are based on maintaining the existing percent load contribution from each source category. The recommended scenario balances the reductions from agricultural and urban sources by maintaining existing watershed loading characteristics. The loadings from source categories were allocated according to their existing loads distribution. For instance, sediment loads from forest lands represent the natural condition that would be expected to exist; therefore, the loading from forest lands was not reduced.

6.4 Consideration of Critical Conditions

The GWLF model is a continuous-simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on the daily water balance accumulated to monthly values. Therefore, all flow conditions are taken into account for loading calculations. Because there is usually a significant lag time between the introduction of sediment to a waterbody and the resulting impact on beneficial uses, establishing these TMDLs using average annual conditions is protective of the waterbody.

6.5 Consideration of Seasonal Variations

The continuous-simulation model used for this analysis considers seasonal variation through a number of mechanisms. Daily time steps are used for weather data and water balance calculations. The model requires specification of the growing season and hours of daylight for each month. The combination of these model features accounts for seasonal variability.

SECTION 7

REASONABLE ASSURANCE AND IMPLEMENTATION

7.1 Reasonable Assurance

Sediment and phosphorus reductions in the TMDLs are allocated according to the source loading characteristics for each watershed. Implementation of best management practices (BMPs) in the affected areas should achieve the loading reduction goals established in the TMDLs. The Blackwater River watershed fecal coliform bacteria implementation plan that was developed by the Commonwealth of Virginia in 2001 should result in substantial reductions in sediment and phosphorus loading through shared BMPs (VADCR 2001). Substantial reductions in the amount of sediment reaching the streams can be made through the planting of riparian buffer zones, contour strips, and cover crops. These BMPs range in efficiency from 20% to 70% for sediment reduction. Implementation of BMPs aimed at sediment reduction will also assist in the reduction of phosphorus loading. Additional phosphorus reductions can be achieved through the installation of more effective animal waste management systems and stone ford cattle crossings. Other possibilities for attaining the desired reductions in phosphorus and sediment include stabilization of stream banks and stream fencing. Further "ground truthing" will be performed in order to assess existing BMPs, and to determine the most cost-effective and environmentally protective combination of future BMPs required for meeting the sediment and nutrient reductions outlined in this report.

7.2 Follow-Up Monitoring

The Department of Environmental Quality will maintain the existing monitoring stations in these watersheds in accordance with its ambient monitoring program. VADEQ and VADCR will continue to use data from these monitoring stations to evaluate improvements in the benthic communities and the effectiveness of the TMDL in attaining and maintaining water quality standards.

Based on the results of EPA's chronic toxicity study for Upper Blackwater River and North Fork Blackwater River, additional toxicity testing and chemical analyses are recommended to verify these results and to further investigate possible toxic effects on aquatic organisms. Monitoring studies may also include the initiation of a special study and/or monitoring of fish tissue. As with other pollutants, if toxic chemicals are found to exist at toxic levels in these streams in the future, then TMDLs will be developed for these constituents as well.

7.3 Regulatory Framework

This TMDL is the first step toward the expeditious attainment of water quality standards. The second step will be to develop a TMDL implementation plan, and the final step is to implement the TMDL until water quality standards are attained. An implementation plan was previously developed to address the bacteria impairments in the watershed (VADCR 2001).

Section 303(d) of the Clean Water Act (CWA) and current EPA regulations do not require the development of implementation strategies. However, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) directs VADEQ in section 62.1-44.19.7 to "develop and implement a plan to achieve fully supporting status for impaired waters". The Act also establishes that the implementation plan shall include that date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated cost, benefits and environmental impact of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process". The listed elements include implementation actions/management measures, time line, legal or regulatory controls, time required to attain water quality standards, monitoring plan and milestones for attaining water quality standards. Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of VADEQ, VADCR and other cooperating agencies.

Once developed, VADEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan, in accordance with the CWA's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and VADEQ, VADEQ also submitted a draft Continuous Planning Process to EPA in which VADEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

7.4 Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. In response to the federal Clean Water Action Plan, Virginia developed a Unified Watershed Assessment that identifies watershed priorities. Watershed restoration activities, such as TMDL implementation, within these priority watersheds are eligible for Section 319 funding. Increases in Section 319 funding in future years will be targeted towards TMDL implementation and watershed restoration. Other funding sources for implementation include the USDA's CREP program, the state revolving loan program, and the VA Water Quality Improvement Fund.

7.5 TMDL Implementation

Implementation of best management practices (BMPs) in the watersheds will occur in stages. The benefit of staged implementation is that it provides a mechanism for developing public support and for evaluating the adequacy of the TMDL in achieving the water quality standard. Implementation of these TMDL will also contribute to ongoing water quality improvement efforts in these watersheds.

7.6 Water Quality Standards

If implementation of reasonable BMPs has failed to improve or restore the benthic community and additional controls would have widespread social and economic impacts, VADEQ has the option of performing a Use Attainability Analysis (UAA) using the factors set forth in 40 CFR ' 131.10(g). A UAA is a structured scientific assessment of the factors affecting the attainment of the use which may include physical, chemical, biological, and economic factors as described in the Federal Regulations. The primary factors to include are as follows: 1. the factor of widespread social and economic impacts 2. human caused conditions and sources of pollution prevent the attainment of the use and cannot be remedied. The stakeholders in the watershed, Virginia, and EPA will have an opportunity to comment on these special studies.

SECTION 8

PUBLIC PARTICIPATION

A stakeholder and TMDL study kickoff meeting was held on November 13, 2002. Important information regarding likely stressors and sources was discussed with state environmental personnel and local stakeholders.

The first public meeting on the development of TMDLs for the Blackwater River watershed was held on January 28, 2003 from 7-10 p.m. at the Community and Hospitality Center located at 52 Franklin Street in Rocky Mount, Virginia. Approximately ten local stakeholders attended the meeting.Copies of the presentation materials were made available for public distribution at the meeting.

The second public meeting on the development of TMDLs for the Blackwater River watershed was held on December 18, 2003 from 7-10 p.m. at the at the Community and Hospitality Center in Rocky Mount, Virginia. Six local statkeholders attended the meeting. Copies of the Draft TMDL report and presentation materials were made available for public distribution at the meeting. One email question was received by VADEQ regarding the effects of sediment load reductions on benthic community composition.

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APPENDIX A

SEDIMENT LOAD ALLOCATIONS

The following tables present the existing and allocated sediment loads and percent reductions for each of the 16 subbasins in the Upper Blackwater River watershed. Table A.1 shows the loads that contribute to the South Fork Upper Blackwater River, Table A.2 shows the loads that contribute to the North Fork, and Table A.3 shows the loads that contribute directly to the mainstem. The tables are arranged to show the existing and allocated sediment loads as they progress downstream from channel to channel. Highlighted in yellow is the total load to each channel segment from various sources including the load from the upstream channel as well as the load contributed directly from the immediate subwatershed. The "channel deposition/erosion" shows the amount of sediment that is deposited or eroded within the current channel segment before it enters the downstream segment; a negative number indicates deposition, while a positive number indicates bank erosion. The "load to downstream channel" is the sum of the "load to channel"and the deposition or erosion. For channel 4 (the downstream-most watershed), the "load to downstream channel" is the amount of sediment exiting from the outlet of the entire impaired watershed.

Table A.1 Recommended sediment reductions by subwatershed for South Fork Blackwater River

South Fork Blackwater	16 (Headwaters)			15			14			13			12		
Source Category	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)
Load Entering From Upstream Contributing Areas*	N/A	N/A		229.0	229.0		376.3	376.3		2447.1	1329.3		2026.3	1033.1	
Row Crop	17.5	17.5	0	46.4	46.4	0	1541.8	724.7	53	686.3	199.0	71	681.3	163.5	76
Pasture/Hay	90.4	90.4	0	126.2	126.2	0	514.0	215.9	58	379.5	107.3	72	221.2	53.1	76
Pasture/Hay (stream access)	1.2	1.2	0	0.8	0.8	0	4.6	2.0	55	3.4	1.2	65	0.0	0.0	0
DeciduousForest	119.4	119.4	0	41.0	41.0	0	93.2	93.2	0	12.4	12.4	0	6.4	6.4	0
MixedForest	0.6	0.6	0	0.2	0.2	0	0.4	0.4	0	0.1	0.1	0	0.1	0.1	0
Urban	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0
Groundwater	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0
PointSource	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.53	0.53	0	0.0	0.0	0
Load to Channel	**229.0**	**229.0**	**0.0%**	**443.6**	**443.6**	**0.0%**	**2530.2**	**1412.4**	**44.2%**	**3529.3**	**1649.8**	**53.3%**	**2935.4**	**1256.3**	**57.2%**
Channel Deposition/Erosion	N/A	N/A		-67.3	-67.3		-83.2	-83.2		-1503.0	-616.7		-890.1	-195.8	
Load to downstream channel	229.0	229.0		376.3	376.3		2447.1	1329.3		2026.3	1033.1		2045.2	1060.5	To Channel 4

Table A.2 Recommended sediment reductions by subwatershed for North Fork Blackwater River

North Fork Blackwater	11 (Headwaters)			10			9			8			7			6			5		
Source Category	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)
Load Entering From Upstream Contributing Areas*	N/A	N/A		242.4	242.4		220.3	216.9		1284.2	1205.7		1260.5	859.4		1834.3	1122.6		2258.4	1105.7	
Row Crop	36.7	36.7	0	0.0	0.0	0	207.3	188.6	9	427.6	158.2	63	498.4	199.4	60	591.7	117.2	80	355.8	46.3	87
Pasture/Hay	114.9	114.9	0	55.7	52.3	6	701.6	645.5	8	174.4	62.8	64	471.8	188.7	60	540.3	107.0	80	100.8	12.1	88
Pasture/Hay (stream access)	0.6	0.6	0	0.7	0.7	0	31.5	29.0	8	2.2	0.9	60	5.9	2.5	58	10.4	2.1	80	1.2	0.1	88
DeciduousForest	89.9	89.9	0	9.4	9.4	0	133.6	133.6	0	10.3	10.3	0	25.8	25.8	0	8.6	8.6	0	3.1	3.1	0
MixedForest	0.2	0.2	0	0.0	0.0	0	0.9	0.9	0	0.1	0.1	0	0.0	0.0	0	0.120	0.120	0	0.1	0.1	0
Urban	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0
Groundwater	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0
PointSource	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.00	0.00	0	0.0	0.0	0	0.0	0.0	0
Load to Channel	**242.4**	**242.4**	**0.0%**	**308.1**	**304.8**	**1.1%**	**1295.1**	**1214.4**	**6.2%**	**1898.8**	**1437.9**	**24.3%**	**2262.5**	**1275.9**	**43.6%**	**2985.4**	**1357.5**	**54.5%**	**2719.3**	**1167.3**	**57.1%**
Channel Deposition/Erosion	N/A	N/A		-87.8	-87.8		-10.8	-8.7		-638.3	-578.5		-428.2	-153.3		-727.0	-251.9		-798.2	-93.0	
Load to downstream channel	242.4	242.4		220.3	216.9		1284.2	1205.7		1260.5	859.4		1834.3	1122.6		2258.4	1105.7		1921.1	1074.3	To Channel 4

Table A.3 Recommended sediment reductions by subwatershed for Upper Blackwater River

Blackwater mainstem	4 (Confluence of 5 & 12)		
Source Category	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)
Load Entering From Upstream Contributing Areas*	From 5 & 12 3966.3**	2134.7**	
Row Crop	1439.3	450.5	69
Pasture/Hay	754.8	234.0	69
Pasture/Hay (stream access)	7.5	2.3	69
DeciduousForest	26.9	26.9	0
MixedForest	0.1	0.1	0
Urban	0.0	0.0	0
Groundwater	0.0	0.0	0
PointSource	0.0	0.0	0
Load to Channel	**6194.9**	**2848.6**	**54.0%**
Channel Deposition/Erosion	-1549.4	-362.5	
Load to downstream channel	4645.5	2486.1	

Sediment TMDLs for each non-headwater channel segments are presented in Table A.4. In order to depict actual loads to the stream, the TMDL presented for each channel originates from the "load to channel" (which is the total load coming from the lands and upstream areas and entering the stream), rather than the "load to downstream channel" (which is the load at the outlet of each subwatershed). Reductions were made and load allocations were assigned to the various sources within each subbasin based on the load to each channel. Bank erosion and channel deposition are accounted for as sediment is routed downstream from channel to channel, and loads due to these instream processes are included in the overall loads to each channel.

Table A.4 Sediment TMDLs by channel for Upper Blackwater River

Channel	Pollutant	TMDL (tons/yr)	LA (tons/yr)	WLA (tons/yr)	MOS (10%) (tons/yr)
4	Sediment	3165.1	2848.6	0.00	316.5
5	Sediment	1297.0	1167.3	0.00	129.7
6	Sediment	1508.4	1357.5	0.00	150.8
7	Sediment	1417.7	1275.9	0.00	141.8
8	Sediment	1597.7	1437.9	0.00	159.8
9	Sediment	1349.4	1214.4	0.00	134.9
10	Sediment	338.6	304.8	0.00	33.9
12	Sediment	1395.9	1256.3	0.00	139.6
13	Sediment	1833.1	1649.3	0.526 (*Callaway Elementary School = 0.0789; VDOT = 0.447*)	183.3
14	Sediment	1569.4	1412.4	0.00	156.9
15	Sediment	492.9	443.6	0.00	49.3

APPENDIX B

TOTAL PHOSPHORUS LOAD ALLOCATIONS

The existing and allocated total phosphorus (TP) loads and percent reductions for each of the 7 subbasins in the North Fork Blackwater River watershed are presented in Table B.1. The tables are arranged to show the existing and allocated TP loads as they progress downstream from channel to channel. Highlighted in yellow is the total TP load to each channel segment from various sources including the load from the upstream channel as well as the load contributed directly from the immediate subwatershed. The "transport loss" shows the amount of TP that is lost within the current channel segment before it enters the downstream segment. The "load to downstream channel" is the "load to channel" minus transport loss. For channel 5 (the downstream-most watershed of the North Fork) the "load to downstream channel" is the amount of TP the mainstem receives from the North Fork.

Table B.1 Recommended phosphorus reductions by subwatershed for North Fork Blackwater River

North Fork Blackwater	11 (Headwaters)			10			9			8			7			6			5		
Source Category	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)	Existing Load (ton/yr)	Allocated Load (ton/yr)	Percent Reduction (%)
Load Entering From Upstream Contributing Areas*	N/A	N/A		0.331	0.331		0.398	0.398		1.790	1.790		2.368	2.030		3.077	2.260		4.083	2.580	
Row Crop	0.032	0.032	0	0.000	0.000	0	0.191	0.191	0	0.361	0.126	0.65	0.439	0.154	0.65	0.504	0.126	0.75	0.297	0.074	1
Pasture/Hay	0.110	0.110	0	0.048	0.048	0	0.731	0.731	0	0.162	0.065	0.6	0.464	0.206	0.6	0.509	0.177	0.652	0.092	0.032	1
Pasture/Hay (stream access)	0.003	0.003	0	0.002	0.002	0	0.062	0.062	0	0.005	0.002	0.65	0.017	0.006	0.65	0.022	0.006	0.75	0.002	0.000	1
Deciduous Forest	0.062	0.062	0	0.007	0.007	0	0.094	0.094	0	0.008	0.008	0	0.019	0.019	0	0.007	0.007	0	0.002	0.002	0
Mixed Forest	0.000	0.000	0	0.000	0.000	0	0.001	0.001	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0
Urban	0.009	0.009	0	0.000	0.000	0	0.024	0.024	0	0.009	0.007	0.2	0.015	0.012	0.2	0.013	0.010	0.2	0.010	0.008	0
Groundwater	0.108	0.108	0	0.013	0.013	0	0.265	0.265	0	0.047	0.047	0	0.116	0.116	0	0.069	0.069	0	0.022	0.022	0
Point Source	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0
Septic System	0.008	0.008	0	0.000	0.000	0	0.029	0.029	0	0.011	0.007	0.4	0.016	0.009	0.4	0.017	0.010	0.4	0.015	0.009	0
Load to Channel	**0.331**	**0.331**	**0.0%**	**0.401**	**0.401**	**0.0%**	**1.794**	**1.794**	**0.0%**	**2.393**	**2.051**	**14.3%**	**3.474**	**2.552**	**26.5%**	**4.218**	**2.665**	**36.8%**	**4.523**	**2.728**	**39.7%**
Transport Loss	N/A	N/A		-0.003	-0.003		-0.004	-0.004		-0.025	-0.021		-0.397	-0.291		-0.135	-0.085		-0.370	-0.200	0
Load to downstream channel	0.331	0.331	0.0%	0.398	0.398	0.0%	1.790	1.790	0.0%	2.368	2.030	14.3%	3.077	2.260	26.5%	4.083	2.580	36.8%	4.280	To Channel 4 2.527	40.9%

Table B.2 presents the total phosphorus (TP) TMDLs for each non-headwater channel segment. (A TMDL for channel 11 is not presented because it is considered part of the headwaters.) In order to depict actual loads to the stream, the TMDL presented for each channel originates from the "load to channel" (which is the total load coming from the immediate contributing lands and the entering stream), rather than the "load to downstream channel" (which is the load at the outlet of each subwatershed). Reductions were made and load allocations were assigned to the various sources within each subbasin based on the load to each channel. The losses and gains of TP due to bank erosion and channel deposition are accounted for as TP is routed downstream from channel to channel, and loads due to these instream processes are included in the overall loads to each channel.

Table B.2 Phosphorus TMDLs by channel for North Fork Blackwater River

Channel	Pollutant	TMDL (tons/yr)	LA (tons/yr)	WLA (tons/yr)	MOS (10%) (tons/yr)
5	TP	3.031	2.728	0.000	0.303
6	TP	2.961	2.665	0.000	0.296
7	TP	2.836	2.552	0.000	0.284
8	TP	2.279	2.051	0.000	0.228
9	TP	1.993	1.794	0.000	0.199
10	TP	0.446	0.401	0.000	0.045